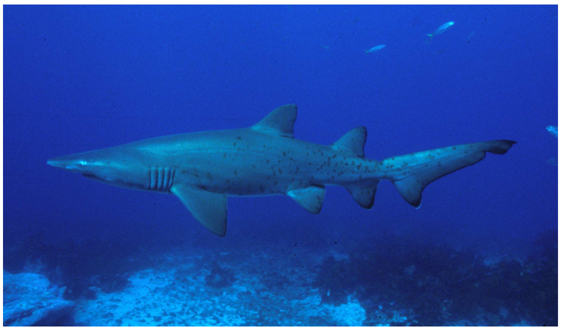

Ecosystem Monitoring of Subtidal Reefs in the Jervis Bay Marine Park 1996-2007

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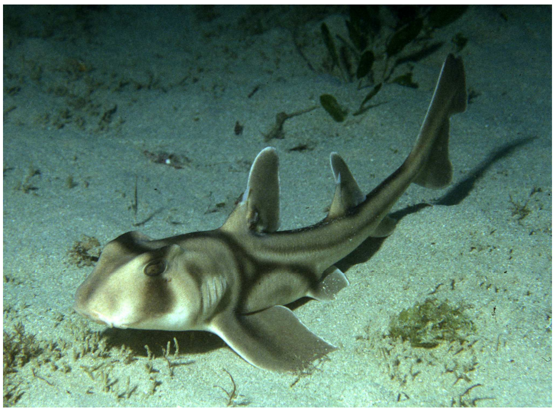

February 2008

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Executive Summary

Surveys of subtidal rocky reefs were conducted in the Jervis Bay Marine Park (JBMP) as part of a broader study into the effectiveness of marine protected areas (MPAs) in Australian temperate waters. The study used the same standardised methodology used in baseline and long-term monitoring programs in Western Australia, South Australia, Tasmania and Victoria. Surveys assessed fish size, diversity and abundance, as well as macro-invertebrate and macro-algal abundance.

Baseline surveys were conducted in 1996 (18 replicate sites), 2000 (24 sites) and 2001 (25 sites). Since establishment of the JBMP zoning plan in October 2002 five surveys in 2003, 2004, 2005, 2006 and 2007 have been completed at 27 sites. Sites were chosen to allow an approximately balanced design between treatments with 14 sites in sanctuary “no-take” zones and 13 reference sites where fishing is still permitted. Sites were also stratified by wave exposure between sheltered and exposed locations.

A diverse fish fauna in excess of 220 species has been recorded. Site attached species such as wrasse, damselfishes, red morwong *Cheilodatylus fuscus* and rock cale *Crinodus lophodon,* provided the most temporally and spatially stable components of the fish assemblage. More mobile and schooling species such as the snapper *Acanthopagrus australis* and yellowfin bream *Pagrus auratus* were highly variable between sites and between years. Newly-recruited juveniles of tropical species, which usually die each winter, also added considerable variation between years.

The invertebrate fauna was dominated by the long-spined urchin *Centrostephanus rodgersii*, while other species such as *Turbo* snails and red-throated ascidians (*Herdmania grandis*) were locally abundant. Commercially and recreationally important abalone and rock lobster species were extremely rare. Algal diversity was relatively low compared to other temperate Australian study locations, with the kelp *Ecklonia radiata* the most common species.

Results from surveys showed population numbers of two species, red morwong and grey nurse shark, diverged between “no take” sanctuary zones established in October 2002 and fished reference sites, and the abundance of “large fish” also diverged through time. Both recovering species exhibited trends for population increase in sanctuary zones, with statistically significant bay-wide increases in abundance for red morwong and a strong single site response for grey nurse sharks. While shark numbers were variable, the re-establishment of grey nurse sharks within a sanctuary zone in Jervis Bay was certainly an encouraging sign that general protection from fishing may help protect this threatened species. The trend for increasing numbers of large fish (300 mm length or greater) within sanctuary zones also indicates that these zones are affording protection to a number of species, and that this change may continue into the future as protected resident species grow.

The other notable pattern observed over the monitoring period was a significant decline in abundance of all common macro-invertebrates, including the common turbo (*Turbo torquatus*) the gastropods *Astraea tentoriformis* and *Astralium squamiferum,* and red-throated ascidians (*Herdmania grandis*). While more time is required to properly determine the biological significance of this trend, it comprises a significant directional response that represents a major shift in the invertebrate

assemblages on JBMP reef systems, with substantial ecosystem consequences likely if the trend continues.

Detection to date of relatively few changes related to protection from fishing is not surprising given that sanctuary zones in the JBMP have only been protected for 4.5 years and, following a one year advisory phrase, prohibitions strongly enforced for only 3.5 years. A more realistic and biologically meaningful timeframe to detect change will be 5-10 years, as resident species recruit to reefs and grow in size. Hence we recommend that annual surveys continue to the five year post protection stage, and then continue at intervals no longer than two years to ten years post protection, when the frequency of the MPA monitoring program should be reviewed. We also note that the value of the monitoring program for coastal management is considerably greater than its value for assessing MPA effectiveness. The annual time series has proved highly useful for detecting significant regional shifts in marine assemblages, and thus represents a critically-important management tool in an era of climate change. For this reason, annual surveys are recommended through the long term, particularly if the evident decline in macro-invertebrate populations is sustained.

1. Introduction

An important component of marine conservation planning in Australia has been the ongoing development of a national system of representative marine protected areas (NRSMPAs) (ANZECC 1999). The current primary goal of Marine Protected Area (MPA) planning and implementation is the conservation of biodiversity. However, MPAs can potentially provide a wide range of additional benefits. For example MPAs can be used in fisheries management to conserve critical habitats and protect spawner biomass. MPAs also act as reference areas for assessing the success of conservation and fisheries management strategies both for single species and ecosystems (Roberts *et al.* 2001; Russ 2002; Ward *et al.* 2001).

To assess the effectiveness of MPAs as a management strategy, monitoring programs are necessary to identify changes that accompany declaration of MPAs, and to identify if these changes result from protection rather than natural variation. In this way monitoring programs can inform MPA planners on which management strategies and design principles are most effective in achieving desired outcomes.

Sound scientific design for monitoring requires replicated surveys both within (treatment) and adjacent (control) to MPAs. It is important as much as practicable for control sites to have similar habitat, oceanographic and geographic characteristics to the protected or treatment areas. Ideally surveys should be repeated multiple times both before the reserves are closed to fishing, and then for a biologically meaningful period following protection. Through the use of time-series sampling designs, the effectiveness of various levels of protection can be distinguished from more general long-term trends that are coincidental to MPA management strategies.

Grants from the Australian Research Council (ARC), Fisheries Research and Development Corporation (FRDC), and assistance from the Commonwealth Government and various State governments have enabled the Tasmanian Aquaculture and Fisheries Institute (TAFI) to undertake baseline and follow-up surveys in a range of proposed Australian temperate MPAs. Study sites have been established in Western Australia, South Australia, Victoria, Tasmania and New South Wales. In each state a common methodology was used that allows for comparison of results between differing locations, MPA designs and management strategies. This information can be used to critique current plans and assist future planning.

In New South Wales, surveys have been conducted at Jervis Bay, located 180 km south of Sydney in the Batemans marine bioregion (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998). The Jervis Bay Marine Park (JBMP) includes approximately 100 km of coastline, and is characterised by a large marine embayment plus 40 km of exposed outer coastline (Fig. 1). The wide entrance to the bay (4 km span) allows prevailing south-easterly swells to enter, with these swells influencing different parts of the bay to differing extents.

Like all NSW marine parks JBMP is zoned for multiple use with approximately 19% of the park's total area closed to all forms of fishing. Although the boundaries of the

JBMP were declared in 1998 it was not until 1st October 2002 that the zoning plan commenced and restrictions on fishing were introduced. The zoning scheme for JBMP encompasses four levels of protection; sanctuary zones, habitat protection zones, general use zones, and special purpose zones.

A total of 14 "no take" sanctuary zones are distributed around JBMP. The sanctuary zones cover a range of habitats from estuarine to exposed coast and protect approximately 30% of the coastline and 20% of the overall park area. Habitat protection zones (HPZ) cover 72% of JBMP and allow recreational fishing, including spearfishing, and restricted (e.g. no trawlers) commercial fishing. Spearfishing is restricted in estuaries and in one small HPZ along the shore near Hyams beach. Trawling is allowed in the two general use zones located outside Jervis Bay which cover 8% of the park. The park also includes two small special purpose zones (SPZ), which are primarily for managing port infrastructure at Huskisson and the Naval base of HMAS Creswell. Public access is restricted in the Creswell SPZ within the area of the harbour. The southern part of Jervis Bay is controlled by the Commonwealth as a marine extension of the Booderee National Park (see Fig. 1) and includes a small SPZ around the western lee side of Bowen Island as well as a long established (ca. 25 years) prohibition on all spearfishing. Collection of intertidal invertebrates is also prohibited within Commonwealth waters.

Barrett *et al.* (2002) provided a comprehensive description of baseline surveys completed in Jervis Bay during 2000 and 2001, while Barrett et al. (2006) provided a description of surveys undertaken in 2004 & 2005. The latter report also evaluated initial changes following protection, including the time series of change dating back to 1996 when a smaller scale (18 sites) baseline study was completed. All surveys utilised identical underwater visual census (UVC) techniques to estimate the abundance of fish and large mobile invertebrates and the percentage cover of common sessile invertebrate and macroalgae before the enforcement of 'no take' zones. The most notable initial change detected was a significant increase in the abundance of *Cheilodactylus fuscus* (red morwong) in the sanctuary zones, presumably as a result of strong fishing effort on this species in the remaining areas surveyed. No other notable change was detected, however this was not unexpected given the short period of full protection of sanctuary zones and the longer time frame required for changes to accumulate through processes such as growth and recruitment.

Since 2001, surveys have been conducted in 2003 just prior to enforcement of zoning regulations, and subsequently in 2004, 2005, 2006 & 2007 following protection. The surveys from 2003 onwards used identical techniques to previous baseline surveys but incorporated more sites to balance the design with respect to the finalised zoning scheme once it was known The surveys undertaken between 2003-07 each investigated 27 sites, comprising 14 sites in sanctuary zones and 13 sites in fished zones, with three sites investigated at two depths.

Biotic assemblages in Jervis Bay fall into two groupings (Barrett *et al.* 2002, 2006), which are dependent on the degree of exposure to sea conditions. Within the two exposure categories of calm and rough, assemblages at different sites displayed a broad similarity between proposed zones and years. This indicated that sites were sufficiently similar between sanctuary and non-sanctuary zones to act as appropriate controls for comparing changes associated with fishing restrictions in sanctuary zones.

The survey methodology is comprehensive, collecting as much information on as many species as possible in the limited field time available. This methodology was designed to maximise detection of (i) changes in population numbers and size-structure of heavily exploited species, (ii) cascading ecosystem effects associated with fishing, (iii) long term change and variability in reef assemblages across the region. The methodology focuses on reef systems as these are generally the most heavily exploited habitats and are therefore likely to show the greatest change following protection.

2. Methods

2.1 Reef monitoring protocol and its rationale

The creation of a mosaic of management zones in the seascape through the declaration of marine protected areas (MPAs) represents an ecological human exclusion experiment at a vast spatial scale (Walters and Holling 1990). The JBMP monitoring method described below was developed to capitalise on this experiment (Edgar & Barrett 1999). It involves underwater visual census of densities of fishes, invertebrates and plants along 200 m transects at replicate sites to quantify biological changes in response to the introduction and enforcement of different management strategies in different areas.

We consider that visual census techniques provide the most effective technique for monitoring species at shallow-water sites in MPAs because they are non-destructive and permit the collection of large amounts of data on a broad range of species within a short dive period. MPA monitoring programs need to cover a range of taxa because, in addition to heavily-exploited species that are predicted to recover in new MPAs, significant secondary effects of fishing are known to also occur that would otherwise go undetected (Babcock *et al.*1999).

The overriding consideration when planning the monitoring design was that temporal change in protected zones provided the primary focus of study. Consequently, spatial variation at the site level that interferes within the detection of the temporal signal was minimised as much as possible. This was done by censusing fixed sites through time, surveying species along set depth contours, sampling in the same season in different years, and aggregating data over a long distance (200 m) per site to smooth fine scale variation.

To minimise natural variation and seasonal effects, sites are fixed and sampled each year over similar dates in late May to early June. The 200 m transect distance is subdivided into four contiguous 50 m long blocks, each of which is 10 m wide for censuses of mobile fishes and 1 m wide for censuses of mobile macro-invertebrates and cryptic fishes. In addition, plants and sessile invertebrates are surveyed 20 times with a 0.25 m^2 quadrat at 10 m intervals along the transect line.

This fixed 'extended-transect' sampling design was selected to maximise the amount of information gathered at each site by three divers, each with a single tank of air. Three sites can be surveyed per day, weather conditions permitting. Pilot trials indicated that if divers reduced the amount of information collected per site, for example by surveying two rather than four 50 m long blocks, then site coverage would not have increased greatly because of the lengthy time required to move between sites (pull anchor, gear up for diving, set transect lines etc). Collection of additional information at each site would require either a second dive team or reduced site coverage.

The collection of data from four 50 m long blocks is best viewed as an approach to increase the precision of estimates of mean values for a 50 m block at a site. Information on spatial substructure within sites – in the form of data from the four contiguous 50 m-long transects – was not used to assess variance within sites. Rather the 200 m transect was subdivided into four blocks because:

1. Data are more easily compared with results of other investigators, who often use transect lengths of 50 m.

2. Different divers can collect information in different 50 m sections of the 200 m length, allowing equitable distribution of dive time regardless of number of divers, and permitting analysis of observer (between diver) effects.

3. If greater precision at a site is required, for example if snapper numbers are highly spatially-variable but are a management priority, then extra 50-m blocks can be added. Similarly, the number of 50-m blocks can be reduced if dive time is limited, such as when surveying deep sites. In both cases, data at the 50-m block scale remain directly comparable with data for other sites.

4. Site data can be partitioned to allow inter-site comparisons of particular habitat types. For example, if a sea urchin barren extends for the first 70 m of a transect followed by 130 m of *Sargassum*, then the first 50 m block provides data on species assemblages in sea urchin barrens, the second 50 m block data on ecotonal zones, and the third and fourth blocks data on fucoid algal habitats. Differences in effects of MPA protection in urchin barrens versus algal habitat can be assessed using these data.

The extended-transect design represents a compromise between power and generality, lying intermediate along the spectrum from more general site studies that involve random replicate transects at each site, and more powerful studies with a single fixed-transect permanently anchored to the seabed.

The extended-transect design is considerably more powerful than a random-transect design, but with less generality in associated statistical tests. Although an understanding of within-site variation can be critical for studies with other aims, individual sites had no intrinsic importance in this MPA study. Our interest was focused on within- and between-zone effects, with sites providing replicate information for analyses. Advantages of random-transect methods over our method are: (i) sites encompass a greater total area of seabed because a range of depths are surveyed at each site rather than a single depth contour, thus increasing generality, and (ii) information is gathered on spatial variance within sites. However, for a study of MPA effects, we considered that these advantages were greatly outweighed by disadvantages. These include: (i) spatial noise associated with randomised placement of transects that obscures the fundamental temporal signal, (ii) lost diving time during periods when divers move to the start of different replicate transects, resulting in reduced data collection per unit time, (iii) difficulties in truly randomising transect placement and spatial biases associated with haphazard placement, and (iv) confounding with depth as a consequence of some sites being relatively flat with little depth range, and others being steeply-sloping and encompassing a large depth range. Depth is better included as an explicit variable within analyses rather than contributing to spatial noise between replicates.

A design involving transects that are permanently attached to the seabed would be more powerful at detecting temporal effects than our design, but at some minor cost in generality and at considerable extra cost in dive time. The cost in generality for a physically-fixed transect design relates to the fact that our transects were relocated on each sampling event within a band that extended ca. 1 m in depth (due in large part to different tidal heights at the time of each survey) and ca. 20 m in horizontal extent (due to imprecision in site relocation). Thus, some spatial 'noise' is added to the temporal 'signal' in our design, reducing power but also reducing the possibility that overall conclusions are affected by anomalous positioning of a transect.

The major reasons for not utilising a physically-fixed transect were threefold. First, the presence of a permanent transect line could affect the results. For instance wave-induced movements of the line may abrade plants and potentially affect the habitat and thus the ecosystem components censused along the transect. Second, management and social issues arise with installation of fixed infrastructure. The NSW Marine Parks Regulation (1999) generally prohibits this type of physical disturbance in a sanctuary zone, requiring special conditions in the research permit. While each case is considered on its merits, the MPAs preference is to avoid such disturbance wherever possible. In addition we recognise the aesthetic values associated with diving in MPAs, and considered that 200 m long ropes or chains permanently attached to the seabed in sanctuary zones, or permanent markers, would represent a visual intrusion to recreational divers. Third, despite the theoretical increase in power to detect temporal signal for physically-fixed transect designs, power is adversely affected in a practical sense by reduced replication. Considerable dive time and cost is required to initially set up permanent transect lines and seabed markers. If transect lines are left attached between surveys, then they need maintenance, perhaps with replacement after two or three years. If lines are strung on each survey between permanent markers such as star picket posts, then dive time is reduced by the extra time required to set the line after locating markers, some of which may disappear between annual surveys.

2.2 Sites

This report focuses on surveys conducted in 2003, 2004, 2005, 2006 and 2007. During each of these sampling periods 27 sites were surveyed (see Fig. 1 & Table 1). Sites were chosen to allow a balanced and replicated design on the basis of zoning and degree of exposure. Sites were limited to areas that have structured reef that is at least 200 m in length at the 5 m contour line. To provide an indication of depth related variation in reef assemblages, three of the exposed sites were surveyed along both the 5 m and 10 m depth contours. Plant and animal assemblages were sufficiently different at the two depths to be considered independent 'sites' in analyses. All sites outside sanctuary zones were grouped as the 'fished' treatment.

Comparisons to surveys conducted in 1996, 2000 and 2001 are based on the 18 sites surveyed in 1996. The 18 site analysis is not as powerful at detecting differences between fished and not-fished treatments because changes to zoning proposals resulted in the original 18 site design becoming relatively unbalanced both in relation to zones (11 sites in sanctuaries and 7 outside) and degree of exposure between the sanctuary and fished areas. Therefore results from surveys conducted in 1996, 2000 and 2001 are used as a time series comparison only.

2.3 Census methodology

At each reef site the abundance and size structure of fish, the abundance of cryptic fish and large benthic invertebrates, and the percent cover of macroalgae and sessile invertebrates were censused separately along the same four 50-m transects. The transect lines were laid end to end along a fixed depth contour (generally the 5 m depth contour, although occasionally approaching shallower depths where reef at 5 m was not available, and at the 10 m contour for some transects). SCUBA divers recorded data on waterproof sheets.

2.3.1 Fishes

The density and estimated size-class of the various fish species within 5 m of each side of the transect line were recorded by a diver swimming up the offshore side of the line and then back along the inshore side in the middle of a 5 m wide lane. Size-classes of total fish length used in the study were 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. Lengths of fish >1 m length were individually estimated. Calibration of size estimates was based on comparison of observed fish lengths with a scale-bar on the underwater slates carried by divers. Double counting of individual fish sometimes occurred when the diver returned along the inshore side of the transect line. Nevertheless, such double counts are appropriate if the inshore and offshore 50 m x 5 m blocks are considered as two separate (albeit non-independent) estimates for the 50 m transect length. The reason that fish were counted on the return leg regardless of whether they were recognised as having been counted on the initial leg was that if this had not been done then return counts would be lower than initial counts, and mean total density estimates not comparable with 50 m x 5 m density estimates of workers elsewhere. Return counts were undertaken to allow greater precision of site estimates, especially for detecting the early recovery of previously rare species, with little extra underwater time – transect lines already having been set.

Fish census data clearly are affected by a range of biases, including observer error and variation in behavioural responses of fish to divers (DeMartini and Roberts 1990; Kulbicki and Sarramega 1999; Thompson and Mapstone 1997). Such biases have been investigated in part and discussed for the transect methods used here (Edgar *et al.* 2004). Despite the existence of census biases, we consider them to be largely systematic and to not greatly confound interpretation of patterns because data will be used for relative comparisons between different management zones only.

Care was taken to ensure that sampling effort for each diver was equitably distributed between sanctuary and fished zone types.

2.3.2 Cryptic fishes and megafaunal invertebrates

To survey cryptic fishes and megafaunal invertebrates, the seabed was searched for a distance of 1 m from the transect line including all visible crevices and overhangs but not overturning boulders. Algae were swept away from the transect to obtain a clear view of the substratum. A total of four 1 m x 50 m transects were surveyed at each site. Most mobile megafaunal invertebrates were counted, including large decapod crustaceans, large gastropods including limpets, bivalves, octopus and echinoderms. Invertebrates not counted were the cryptic species or those too small to be accurately counted in the time available per survey. The maximum shell length of abalone and the carapace length of rock lobsters were measured underwater using vernier callipers whenever possible. Cryptic fishes were also identified, counted and the size estimated. Numbers of red-mouthed ascidians (*Herdmania grandis*) were also counted.

2.3.3 Macroalgae and sessile invertebrates

The density of macroalgae and attached invertebrate species was quantified by placing a 0.25 m^2 quadrat at 10 m intervals along transect lines. Macroalgal cover was assessed by identifying and counting algae species that occurred directly under 50 grid positions, comprising 49 intersections of seven wires strung both horizontally and vertically across the quadrat plus one corner. Algae were counted in layers, with percent cover of dominant overstorey species recorded first. These were then pushed aside, exposing the understorey species. Unknown or unidentifiable species were assigned into higher taxonomic or functional categories. A total of 5 m^2 was surveyed at each site. Some invertebrates not covered in the invertebrate counts were counted in the macroalgae quadrats as an abundance per 0.25m^2 rather than an overall % cover.

2.4 Statistical Analysis

The monitoring design can be considered as a replicated Before-After-Control-Impact (BACI) design (Green 1979) that can be analysed using repeated-measures ANOVA, with year and management zone fixed factors. However, much information on variation within and between zones is lost with an ANOVA approach because sites in all zones of the same type are considered equal. Variation between sites in biological response to protection from fishing (resulting from factors such as distance from the reserve boundary, or level of pre-existing fishing pressure) possesses intrinsic interest and should be recognised, rather than adding to noise between replicates. An additional disadvantage of ANOVA designs for long-term monitoring programs is that time components need to be blocked in some way.

Nevertheless, ANOVA is most useful as a statistical tool in the early stages of monitoring programs when little time series data are available post MPA declaration. For the JBMP, two-way repeated-measures ANOVAs were conducted with year and treatment as the fixed factors. Data for species abundances was log (x+1) transformed to enable the detection on multiplicative (rather than additive) changes. Data for species richness and algal percentage cover were not transformed before analysis.

Once several years of post MPA declaration data are available, curvilinear modelling techniques should comprise the most useful of available methods for investigating MPAs. Using non-linear regression or generalised linear models, for example, one can quantify relationships between biological response to protection and variables such as time since MPA declaration, management zone size, distance from MPA boundary, reef habitat complexity, and fishing pressure prior to declaration of the MPA. Effect size is readily estimated as the difference between the value of a variable at any point in time and the mean of baseline values for that variable at the same site prior to MPA declaration.

Relative changes over time in plant and animal communities were examined graphically using non-metric multidimensional scaling (MDS). Data input to matrices for multivariate analyses were square root transformed to reduce the influence of the abundant species, and converted to a symmetric matrix of biotic similarity using the Bray-Curtis similarity index, which is relatively insensitive to data sets with many zero values. The usefulness of the two dimensional MDS display of biotic relationships is indicated by the stress statistic, which signifies a good depiction of relationships when <0.1 and poor depiction when >0.2 (Clarke, 1993).

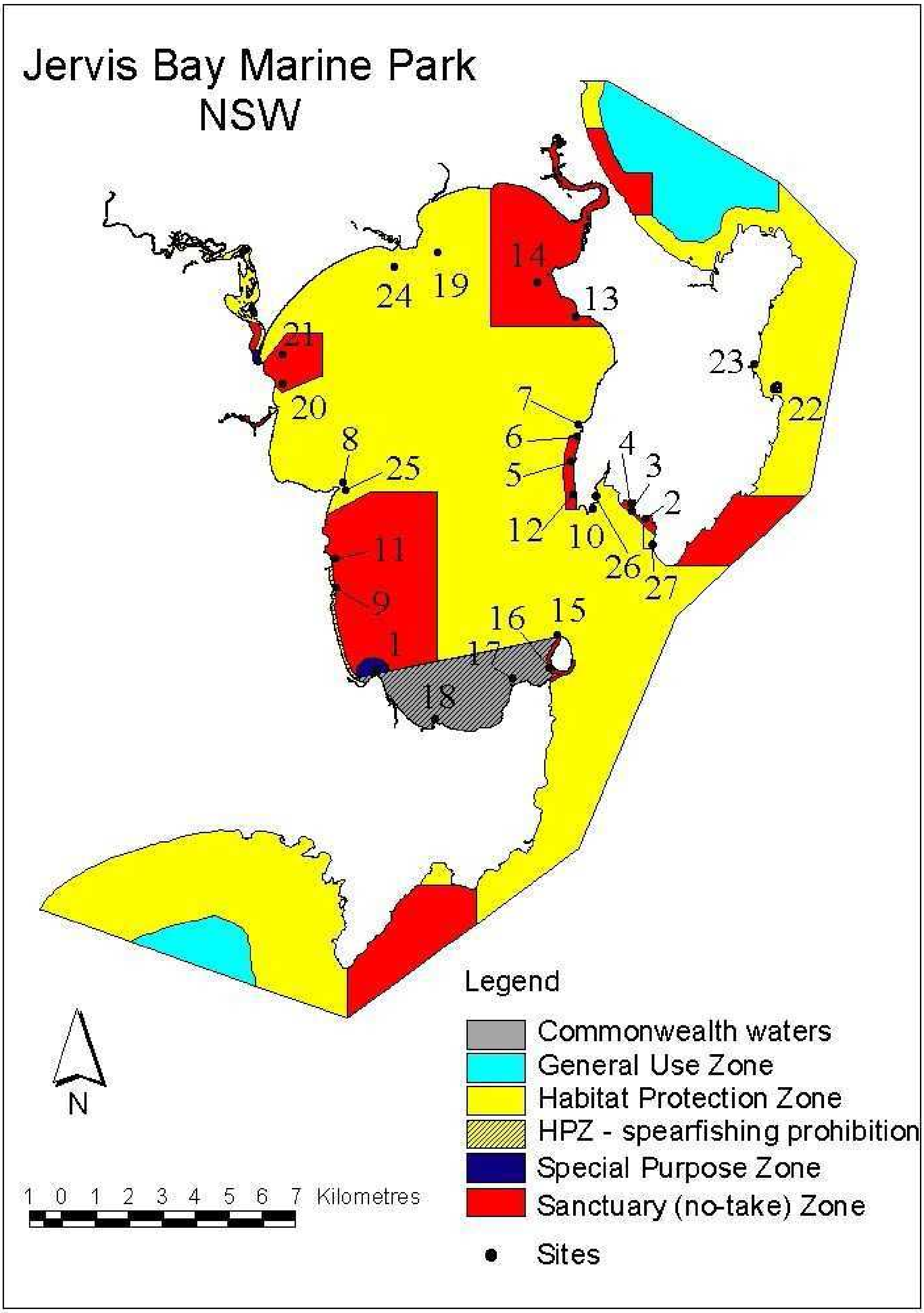


Figure 1. Map showing the location of sites surveyed in the Jervis Bay Marine Park. Commonwealth waters in Jervis Bay south of the line between HMAS Creswell (Site 1) and the northwest tip of Bowen Island (Site 15) comprise a marine extension of Booderee National Park, where spearfishing is prohibited. Site 16 is closed to all fishing.

Table 1. Site details for locations surveyed in Jervis Bay.

Positions were obtained as ten-minute averages using a hand held Garmin GPS. All sites are in decimal degrees using WGD 84.

Site Code	Site	Zone	Latitude	Longitude	Depth (m)
1	Captains Pt (HMAS Creswell)	Special purpose	35.12097	150.70788	5
2	The Docks 1/dive site gulch	Sanctuary	35.08142	150.79732	5,10
3	The Docks 2/canon (Black Boat Cove (South)	Sanctuary	35.07993	150.79300	5,10
4	The Docks 3/bay (North Black Boat Cove)	Sanctuary	35.07768	150.79223	5
5	Honeymoon Bay 1 km S (Blue Hole)	Sanctuary	35.06610	150.77299	5
6	Honeymoon Bay 300m S (Grouper Coast north)	Sanctuary	35.05942	150.77500	5
7	Honeymoon Bay 150 m N (Bindajine Point)	Habitat Protection	35.05592	150.77558	5
8	Plantation Point North	Habitat Protection	35.07022	150.69838	5
9	Hyams Beach (Chinamans Reef)	Habitat Protection	35.09882	150.68847	5
10	Longnose Point	Habitat Protection	35.07878	150.77982	5
11	Greenfield Beach (Point)	Sanctuary	35.09058	150.02790	5
12	Dart Point East (Grouper Coast south)	Sanctuary	35.07469	150.77344	5
13	Montague Point	Sanctuary	35.02708	150.77568	5
14	Green Point (Green Island)	Sanctuary	35.01620	150.76487	5
15	Bowen Island NW	Sanctuary	35.11272	150.76720	5
16	Bowen Island SW	Sanctuary	35.12113	150.76417	5
17	Murrays Point (Murrays Reef)	Cmw non-sanctuary	35.12393	150.75235	5
18	Bristol Point/Greenpatch	Cmw non-sanctuary	35.13438	150.72665	5
19	Callala	Habitat Protection	35.00885	150.73107	5
20	Husky Caravan Park	Sanctuary	35.04315	150.67925	5
21	Tapalla Point (Husky reef)	Sanctuary	35.03550	150.67965	5
22	Drum and Drumstick	Sanctuary	35.04780	150.83995	5
23	Drum and drumstick north (Gumgetters)	Habitat Protection	35.04068	150.83387	5
24	Callala reef west	Habitat Protection	35.01242	150.71650	5
25	Plantation Point South	Habitat Protection	35.07227	150.69913	5
26	Outer Tubes	Habitat Protection	35.08773	150.79903	5,10
27	Longnose South	Habitat Protection	35.08182	150.77778	5

3. Results

3.1 Fish

Community characteristics

A high diversity of fish species was encountered during the Jervis Bay surveys, with 216 species recorded over the 7 survey periods. Species richness was relatively stable with an average of 115 species recorded in any given year. However, large variation between years was evident in the actual fish species sighted with over half (111 species) recorded in only one or two survey periods. This variation is largely due to intermittent encounters with uncommon pelagic species and episodic recruitment of tropical species that recruit to Jervis Bay during the warm summer period but presumably do not survive through winter. In addition to the rarer species, a large component of species are permanently established in Jervis Bay, with over 60 fish species occurring in every survey period. Densities of each fish species at each site are shown in Appendix 1 for 2007, with data for previous years given in Barrett *et al.* (2002, 2005).

Overall biotic community changes between sites and years for fishes for sanctuary zones are depicted using MDS in Fig. 2. Sites with high levels of biotic similarity lie adjacent to each other while sites with few similarities are positioned at distance. The only clear grouping is a division between exposed and sheltered sites confirming results from Barrett *et al.* (2002). As expected, individual sites showed some variability in assemblage structure over the four year period examined, however there was no consistent pattern regarding directional change and no evidence of divergence between levels of protection. A relatively high stress level (0.16) is associated with this figure indicating that care should be taken in interpretation, as much of the variance between sites cannot be accommodated in a two-dimensional plot.

Abundance

The most abundant fish species were generally schooling species such as *Trachinops taeniatus* (eastern hulafish), *Trachurus novaezelandiae* (yellow-tail scad), *Atypichthys strigatus* (mado sweep), and *Schuettea scalaripinnis* (eastern pomfret), with these species dominating the assemblages at many locations. Another schooling species, *Chromis hypsilepis* (one-spot puller), was abundant only at wave-exposed sites. Other common and widespread species included *Pempheris compressa* (small-scale bullseye), *Parma microlepis* (white-ear), *Opthalmolepis lineolata* (maori wrasse) and *Notolabrus gymnogenis* (crimson-banded wrasse). A substantial number of additional species were locally abundant but showed no clear patterns in distribution, suggesting that they either had tight habitat preferences or that counts were affected by chance encounters with aggregations or schools. A notable species with strong site affinities was *Girella tricuspidata* (luderick), a fish only encountered in significant numbers at the most wave-exposed sites.

Figures 3 and 4 show the variation between sanctuary and non-sanctuary zones for common fish species based on survey results from 1996 to 2007 and 2003-2007 respectively. Figure 3 contains a smaller (18) subset of sites sampled each year since

1996. Figure 4 contains the full number of sites (27) surveyed since the MPA was declared. For the majority of species no clear and/or statistically significant differences in abundance arose between the protected and fished sites over the first four years of protection (Figs 3 & 4, Table 2). The one clear exception was the exploited fish species *Cheilodactylus fuscus* (red morwong), which increased in numbers in sanctuary zones compared to fished zones based on the full dataset (Fig. 4). Its population is estimated to have increased by al least 30% in sanctuary zones relative to fished zones (Fig. 4), and this trend is statistically significant when examined as a repeated measures ANOVA (P=0.016, Table 2). This species is presumably a long-lived reef resident with a high degree of site-attachment. *Cheilodactylus fuscus* is likely home-ranging (Schroeder *et al.* 1994), as are the closely related species *Cheilodactylus spectabilis* in New Zealand and Tasmania (McCormick 1989, Murphy and Lyle 1999) and *Cheilodactylus nigripes* in South Australia (Cappo 1995). An examination of changes in the size distribution of *C. fuscus* over the four years of protection (Fig. 5) shows that much of the increase on numbers within the sanctuary zone is due to increasing numbers of larger animals rather than accumulation of new recruits.

Trends in abundance for a wide range of species were examined using repeated measures ANOVA to see if any significant patterns had arisen after 4 years of protection (Table 2). Apart from *C. fuscus*, the only significant Year x Zone interaction was *Trachinops taeniatus* (P = 0.008), and this result was clearly not related to any accumulating trend (Figs 3 & 4). The analysis for *Pagrus auratus* was almost significant (P= 0.051), with numbers in sanctuary zones increasing relative to fished zones over this period (Fig. 4); regardless, the low numbers of this species recorded and variability between years suggest that this trend should be regarded with caution.

Two species of particular interest to fishers are the bream *Acanthopagrus australis* and the snapper *Pagrus auratus*. While both bream and snapper numbers were trending upwards in the 2005 survey, they have since declined to low levels (Figs 3 & 4, Appendix 1) and only form a minor component of the fish assemblages present at most sites. Significance tests for these species were negatively affected by the highly variable nature of counts between sites and between years, possibly reflecting the mobile nature of juveniles. Few adults were recorded in Jervis Bay during surveys.

Many of the wrasse species displayed a similar pattern of site distribution and relative abundance between years, with abundances rarely varying by more than 50% between years (Figures 3 & 4). This is consistent with past research of temperate Australian wrasse that suggests these fishes are generally long-lived site-attached reef residents with stable population structures (Barrett, 1995, 1997). This appears to be the case for many of the wrasses at Jervis Bay including *Achoerodus viridis* (eastern blue grouper), *Pictilabrus laticlavius* (senator wrasse), *Ophthalmolepis lineolatus* (maori wrasse) and *Eupetrichthys angustipes* (snakeskin wrasse).

A similar pattern was observed for *Crinodus lophodon* (rock cale) and for the damselfishes *Parma microlepis* (white-ear) and *Chromis hypsilepis* (one-spot puller). Damselfishes are a strongly site-attached group (Thresher 1984) with consistency in population structure to be expected whenever several age classes are represented in the population. *Chromis hypsilepis* numbers were remarkably similar between years given that this species is often encountered hovering above the reef in schools feeding on plankton; however, despite this general stability, numbers in 2007 represented a substantial decline from previous years.

More variation was evident in the most common schooling species *Trachinops taeniatus* (hula fish) and *Trachurus novaezelandiae* (yellowtailed scad) (Figs 3 & 4). For the majority of sites where *Trachinops* was present, abundance estimates varied less than 50% (Appendix 1), presumably reflecting the site-attached nature of this species. *Trachurus* was more variable between years, as expected given that it is a pelagic schooling species and that chance encounters with mobile schools generally contribute greater variation to estimates than chance encounters with individuals.

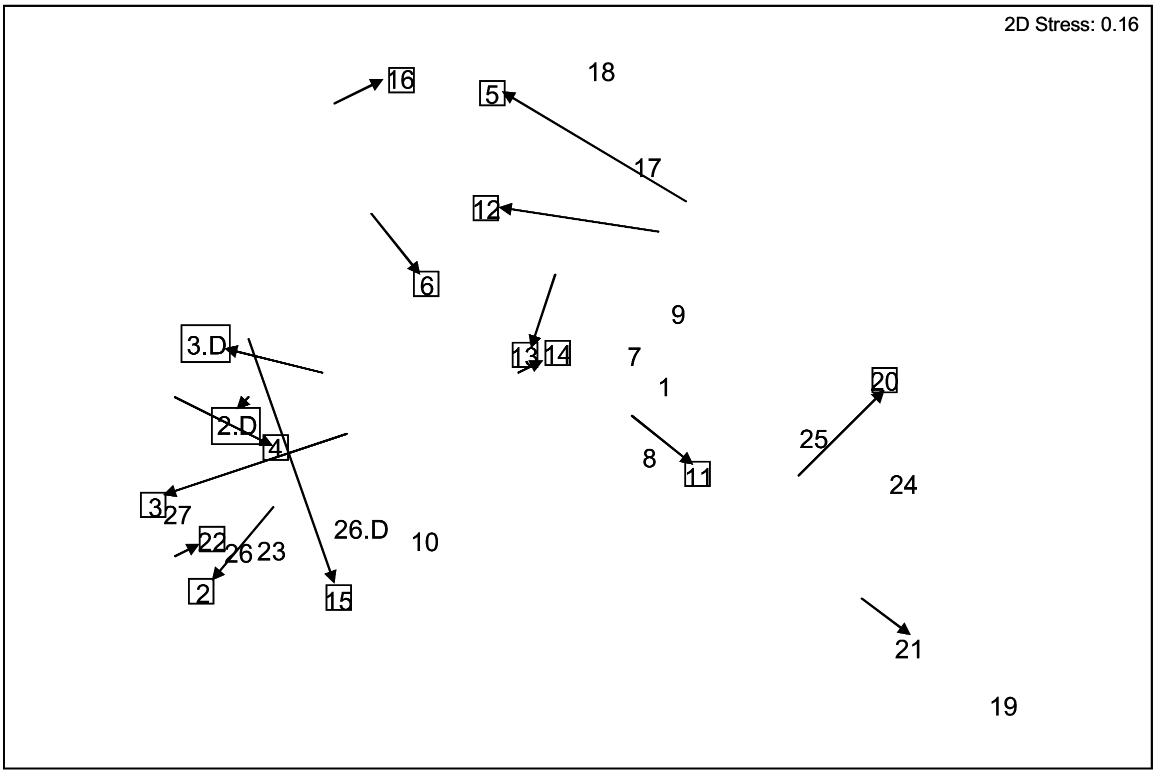


Figure 2. Two-dimensional MDS plot showing the relationship between sites based on 2007 fish assemblage data. Arrows show change from 2003 (pre-protection) to 2007 for sites located in sanctuary zones. Sanctuary site labels are placed in a square and sites surveyed at 10 m depth are shown with a "D" suffix.

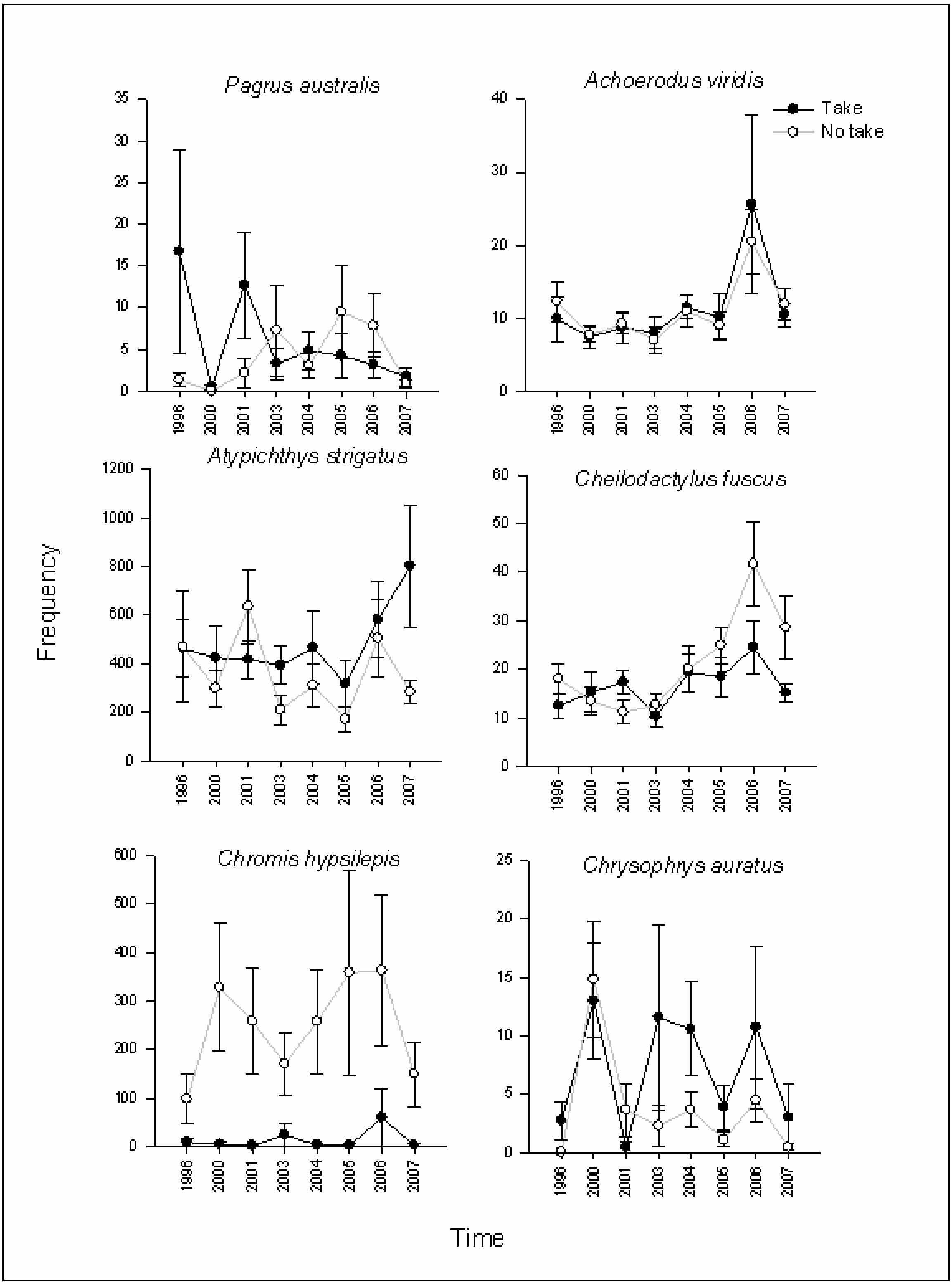
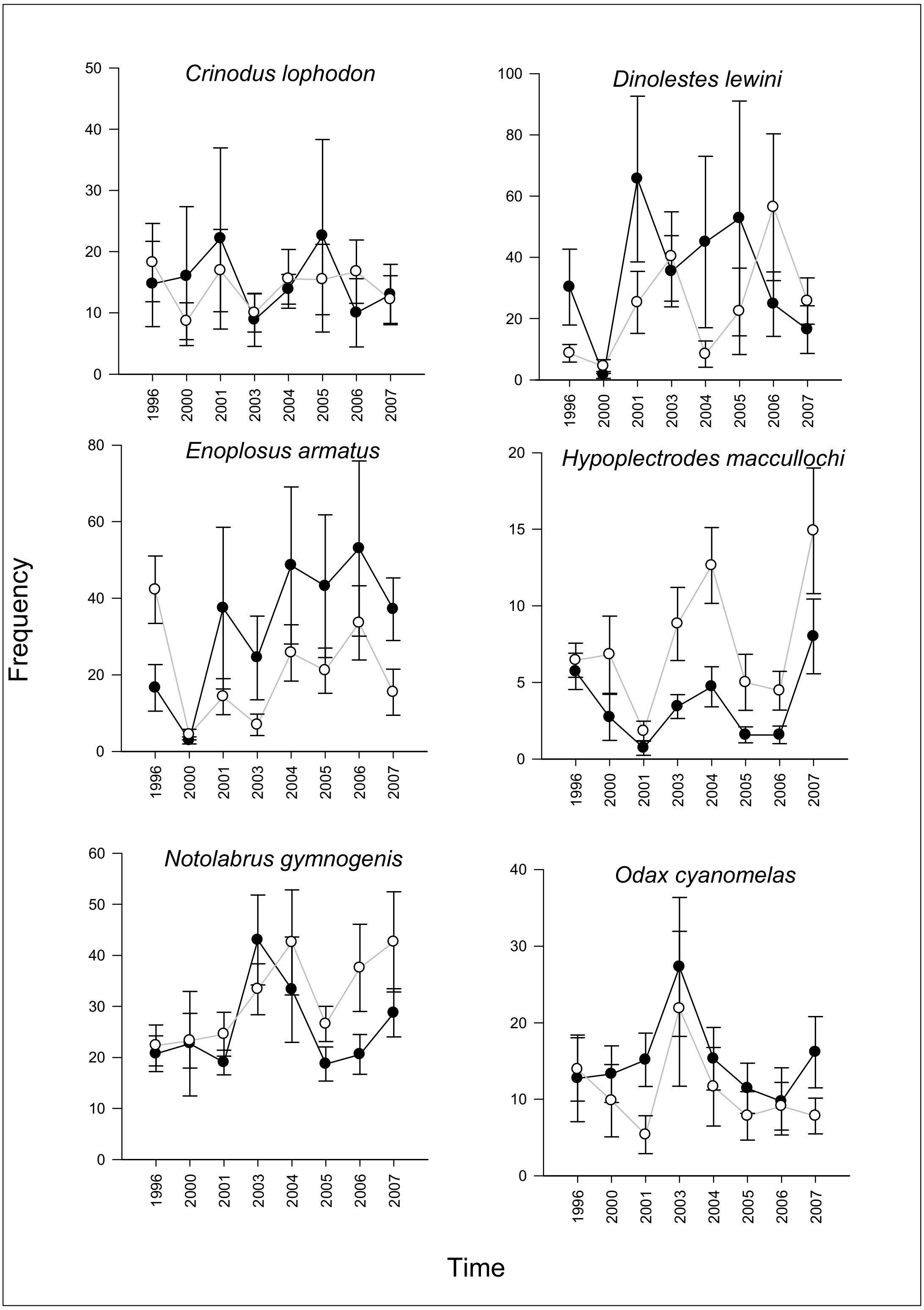


Figure 3. Inter-annual variation in the mean per site abundance of common fishes censused during surveys at sites 1 to 18 in 1996 in 1996, 2000, 2001, 2003, 2004, 2005, 2006 and 2007 at 5m depth contour. [Sites 2 and 3 are excluded in 1996 as they were only conducted at 10 m depth.]



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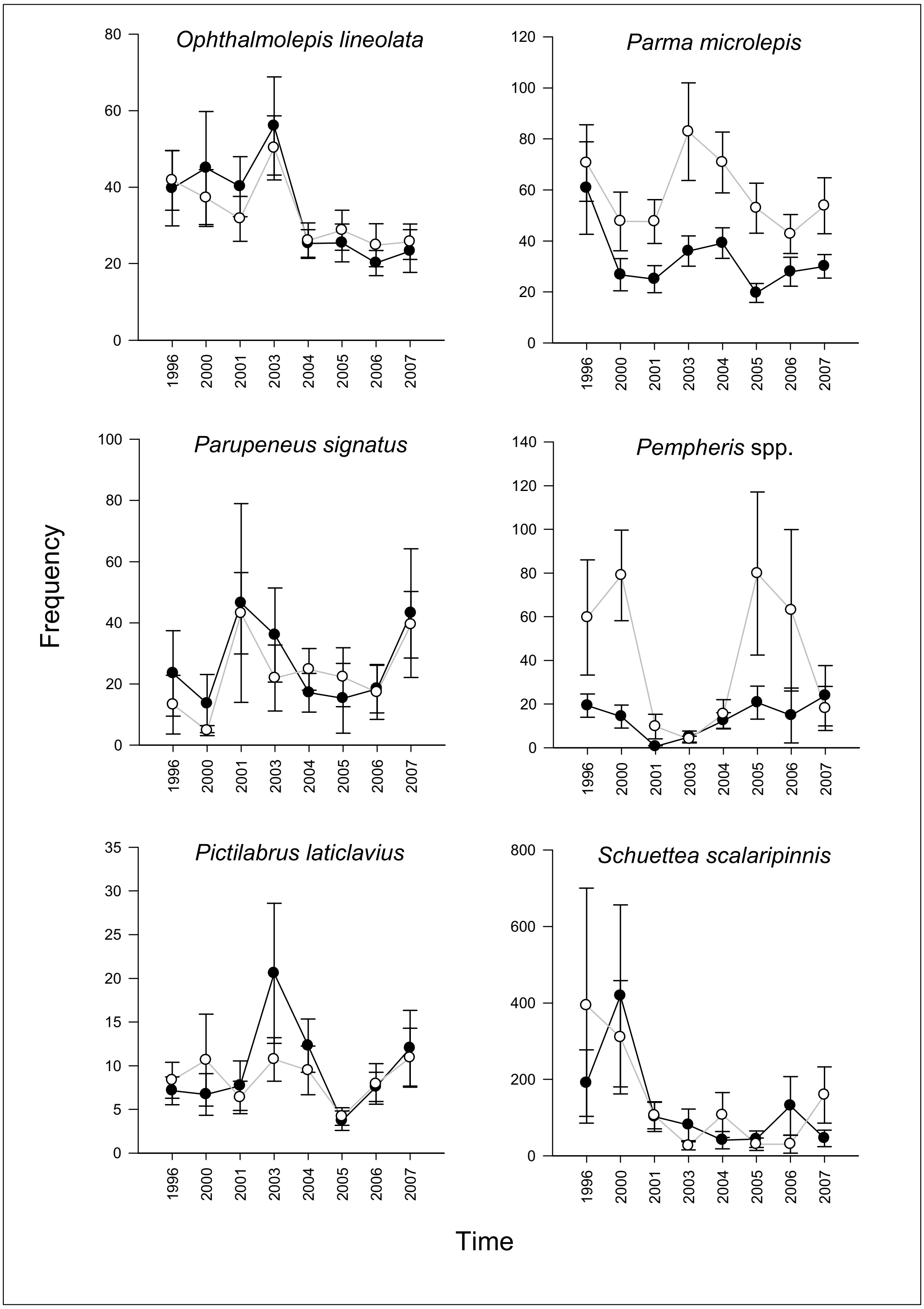

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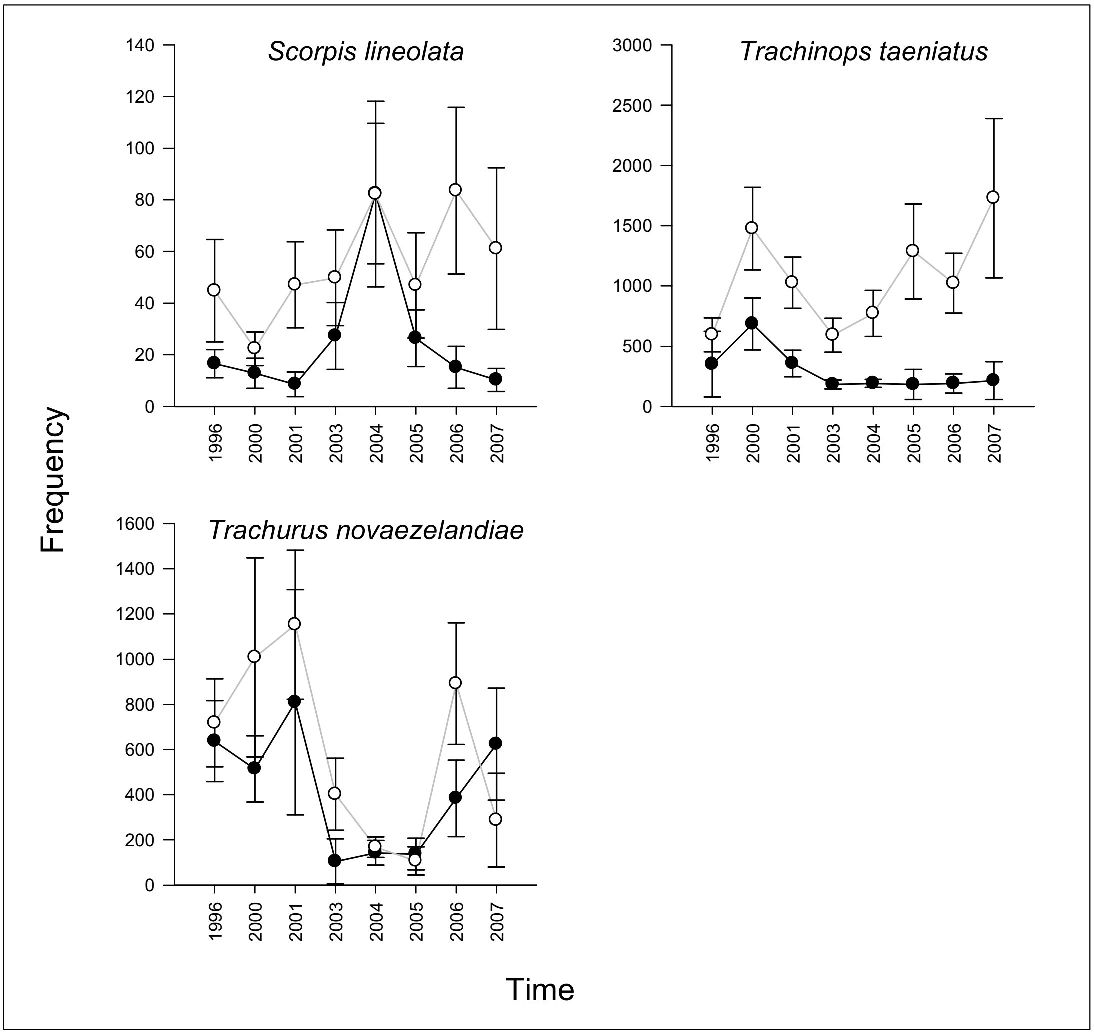

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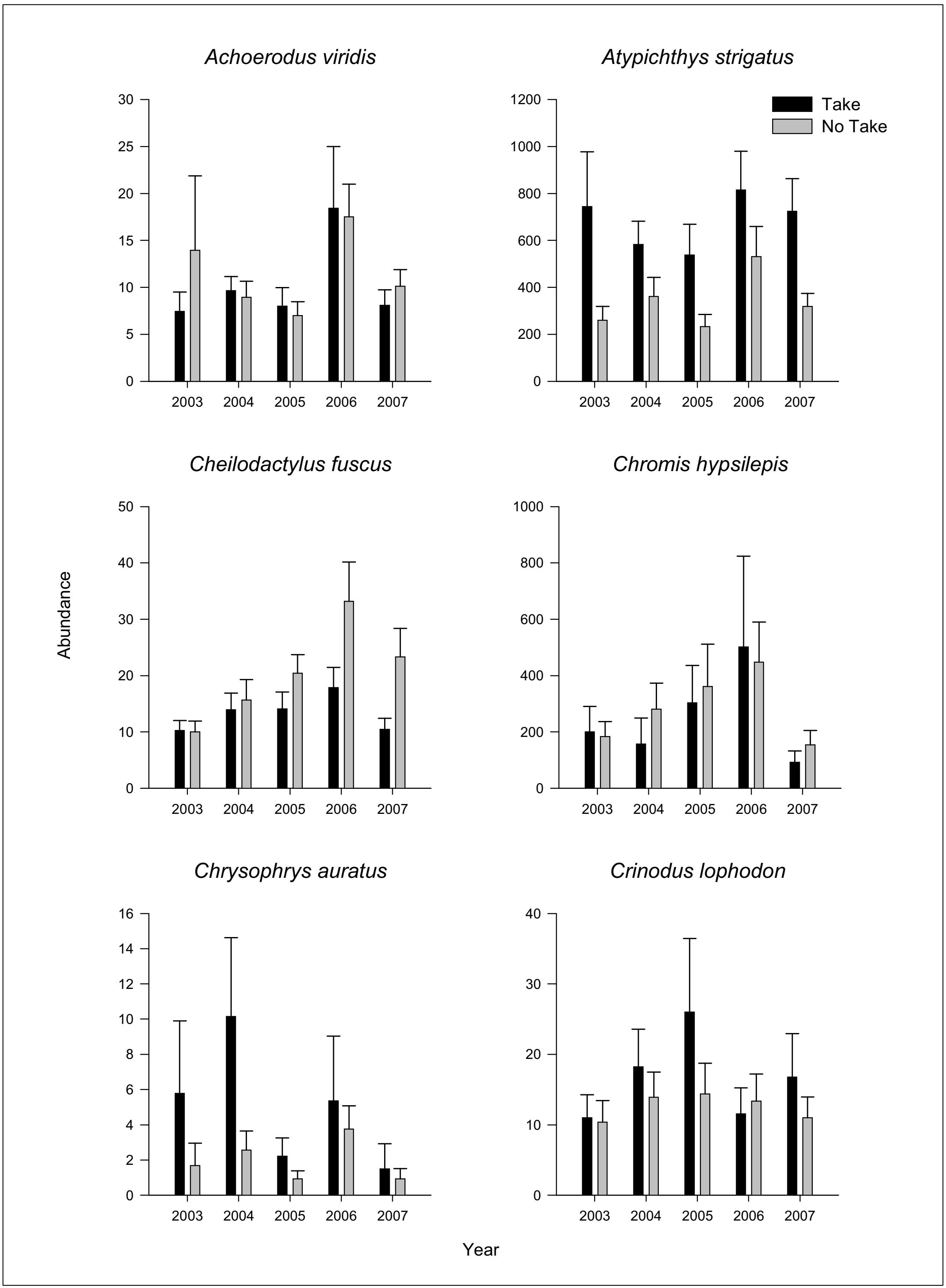
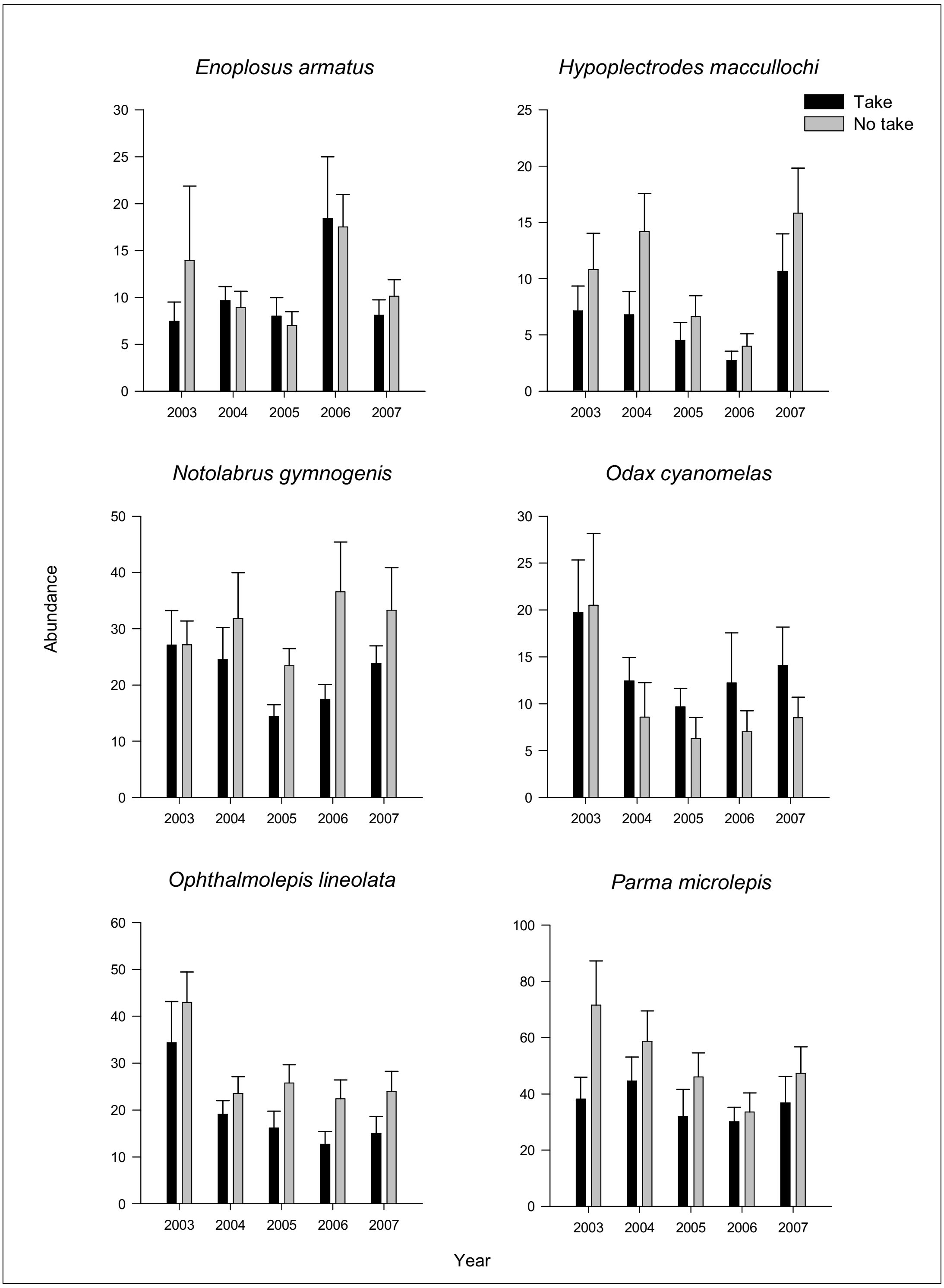


Figure 4. Between zone variation in the mean per site abundance of common fishes censused during surveys at sites 1 to 27 in 2003 to 2007.



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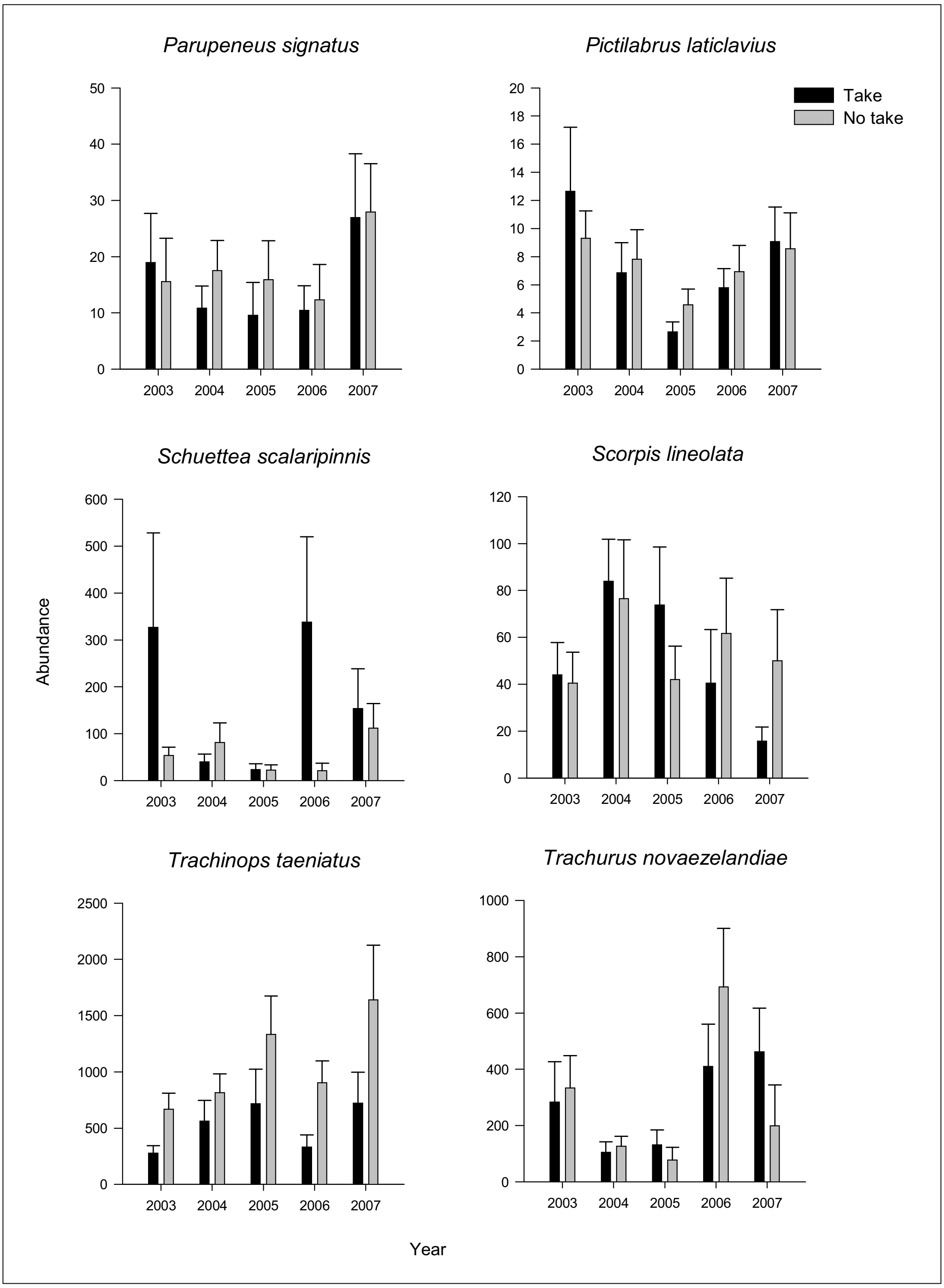

Figure 4. (Continued)

Table 2. Results of repeated measures ANOVAs (fixed factors year and zone) using annual fish data for the period 2003 to 2007 from the 27 sites surveyed at Jervis Bay.

Source	SS	df	MS	F	P
Acanthaluteres vittiger					
Zone	3.674	1	3.674	2.151	0.154
Error	47.83	28	1.708		
year	0.44	4	0.111	0.246	0.911
year*Zone	0.76	4	0.19	0.422	0.792
Error	50.51	112	0.451		
Acanthopagrus australis					
Zone	0.094	1	0.094	0.034	0.855
Error	77.69	28	2.775		
Year	2.304	4	0.576	0.613	0.654
Year* Zone	1.086	4	0.271	0.289	0.885
Error	105.3	112	0.94		
Achoerodus viridis					
Zone	0.058	1	0.058	0.027	0.87
Error	60.05	28	2.145		
Year	1.307	4	0.327	0.976	0.424
Year* Zone	0.804	4	0.201	0.6	0.663
Error	37.51	112	0.335		
Atypichthys strigatus					
Zone	20.59	1	20.592	8.322	0.007
Error	69.29	28	2.474		
Year	2.566	4	0.641	0.734	0.57
Year* Zone	1.588	4	0.397	0.454	0.769
Error	97.819	112	0.873		
Aulopus purpurissatus					
Zone	2.88	1	2.88	4.541	0.042
Error	17.76	28	0.634		
Year	0.2	4	0.05	0.327	0.859
Year* Zone	0.326	4	0.082	0.533	0.712
Error	17.13	112	0.153		
Cheilodactylus					
Zone	3.87	1	3.873	1.298	0.264
Error	83.52	28	2.983		
year	2.11	4	0.526	2.007	0.098
year* Zone	3.37	4	0.834	3.18	0.016
Error	29.4	112	0.262		
Chelmonops truncatus					
Zone	0.733	1	0.733	0.263	0.612
Error	78.13	28	2.79		
Year	0.764	4	0.191	0.595	0.667
Year* Zone	0.348	4	0.087	0.271	0.896
Error	35.97	112	0.321		
Pagrus auratus					
Zone	1.573	1	1.573	0.547	0.466
Error	80.5	28	2.875		
Year	7.836	4	1.959	3.39	0.012
Year* Zone	5.645	4	1.411	2.443	0.051
Error	64.71	112	0.578		
Crinodus lophodon					
Zone	0.004	1	0.004	0.001	0.979
Error	145.4	28	5.191		
Year	1.788	4	0.447	1.015	0.403
Year* Zone	0.908	4	0.227	0.516	0.724
Error	49.32	112	0.44		
Heterodontus portusjacksoni					
Zone	0.065	1	0.065	0.412	0.526
Error	4.414	28	0.158		
Year	0.269	4	0.067	1.026	0.395
Year* Zone	0.371	4	0.093	1.414	0.237
Error	7.34	112	0.066		
Meuschenia freycineti					
Zone	1.795	1	1.795	2.725	0.11
Error	18.44	28	0.659		
Year	1.029	4	0.257	0.9	0.467
Year* Zone	2.14	4	0.535	1.873	0.12
Error	32	112	0.286		

Source	SS	df	MS	F	P
Meuschenia flavolineata					
Zone	1.048	1	1.048	0.282	0.599
Error	103.9	28	3.713		
Year	1.51	4	0.377	1.824	0.132
Year* Zone	1.047	4	0.262	1.265	0.289
Error	23.18	112	0.207		
Notolabrus parilus					
Zone	1.367	1	1.367	0.589	0.449
Error	64.96	28	2.32		
Year	2.178	4	0.544	2.615	0.039
Year* Zone	1.491	4	0.373	1.791	0.136
Error	23.32	112	0.208		
Odax cyanomelas					
Zone	7.957	1	7.957	1.663	0.208
Error	134	28	4.785		
Year	3.487	4	0.872	1.391	0.242
Year* Zone	3.006	4	0.751	1.199	0.315
Error	70.2	112	0.627		
Ophthalmolepis lineolata					
Zone	8.752	1	8.752	3.126	0.088
Error	78.4	28	2.8		
Year	3.095	4	0.774	3.413	0.011
Year* Zone	1.162	4	0.291	1.281	0.282
Error	25.4	112	0.227		
Parupeneus signatus					
Zone	0.28	1	0.28	0.034	0.855
Error	231.1	28	8.252		
Year	3.995	4	0.999	1.241	0.298
Year* Zone	2.968	4	0.742	0.922	0.454
Error	90.16	112	0.805		
Pictilabrus laticlavius					
Zone	0.146	1	0.146	0.031	0.861
Error	131.1	28	4.681		
Year	4.109	4	1.027	3.842	0.006
Year* Zone	1.833	4	0.458	1.714	0.152
Error	29.95	112	0.267		
Prionurus microlepidotus					
Zone	0.463	1	0.463	0.219	0.643
Error	59.16	28	2.113		
Year	4.579	4	1.145	2.191	0.074
Year* Zone	3.399	4	0.85	1.627	0.172
Error	58.5	112	0.522		
Scobinichthys granulatus					
Zone	0.399	1	0.399	0.453	0.506
Error	24.67	28	0.881		
Year	1.386	4	0.346	1.158	0.333
Year* Zone	1.047	4	0.262	0.875	0.482
Error	33.51	112	0.299		
Scorpaena cardinalis					
Zone	0.157	1	0.157	0.495	0.488
Error	8.895	28	0.318		
Year	0.499	4	0.125	0.933	0.448
Year* Zone	0.818	4	0.204	1.528	0.199
Error	14.98	112	0.134		
Trachinops taeniatus					
Zone	24.29	1	24.293	1.115	0.3
Error	609.9	8	21.784		
Year	15.86	4	3.966	4.521	0.002
Year* Zone	12.75	4	3.186	3.633	0.008
Error	98.24	112	0.877		
Trachurus novaezelandiae					
Zone	3.805	1	0.805	0.34	0.564
Error	313.2	28	11.187		
Year	0.391	4	10.098	1.668	0.162
Year* Zone	54.72	4	13.68	2.26	0.067
Error	678.1	112	6.054		
Total species					
Zone	0.607	1	0.607	2.362	0.136
Error	7.189	28	0.257		
Year	0.133	4	0.033	2.759	0.031
Year* Zone	0.05	4	0.013	1.049	0.385
Error	1.346	112	0.012		

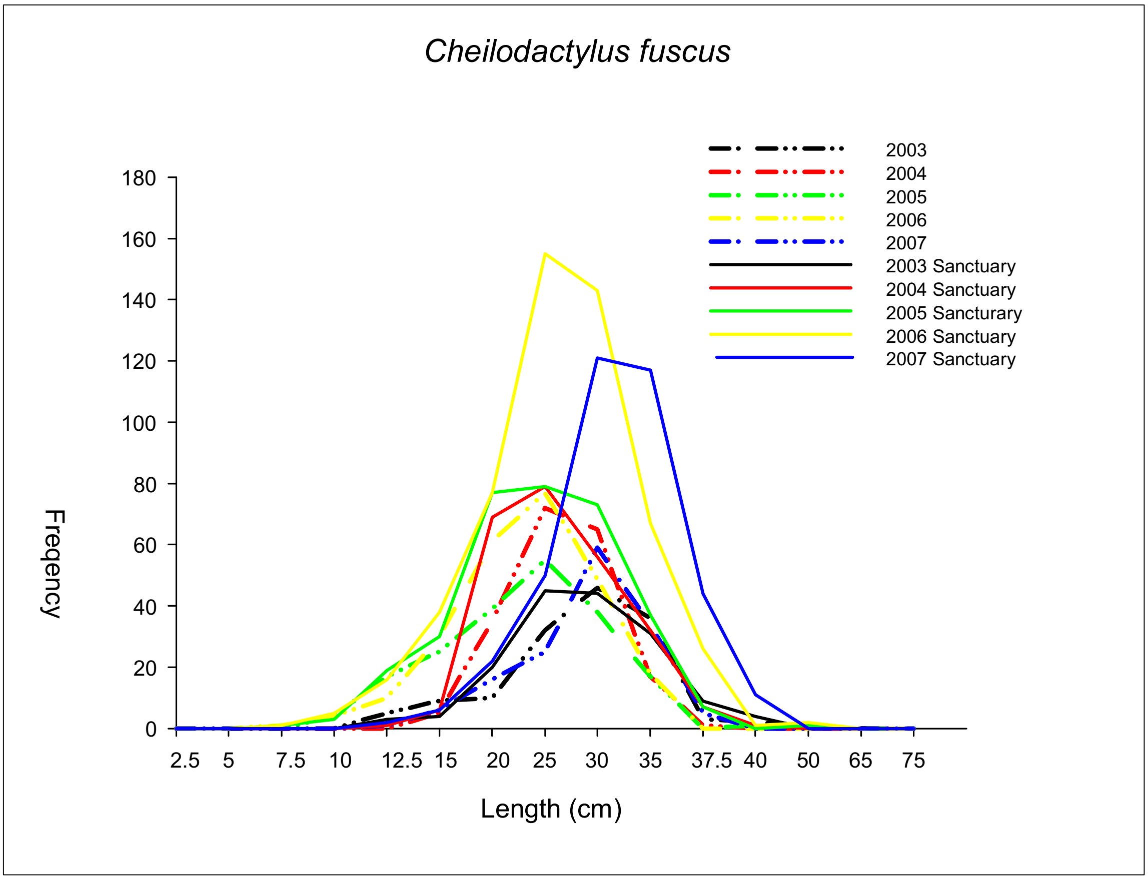

Figure 5. Size distribution of *Cheilodactylus fuscus* within the Jervis Bay MPA during surveys undertaken between 2003 and 2007.

Size distribution

One of the more common responses to protection is an increasing abundance of larger fish, similar to the pattern previously described for *C. fuscus*. While at a single species level such changes may not always be evident due to low abundances and low statistical power, when all species are combined, patterns may become evident. To explore this we first examined the response to protection in: (i) the abundance of all large fish (300 mm estimated length or greater; Fig. 6a), (ii) abundance of large fishes excluding pelagic species (Fig. 6b), (iii) large fishes that are potential target and bycatch species (Fig. 6c), (iv) large fishes that are target species, excluding potentially non-resident target species such as zebrafish and luderick (Fig. 6d), and large fishes that are target species and excluding *C. fuscus*, to examine the influence of *C. fuscus* on the overall pattern (Fig. 6e). In all cases there was a clear increase in the unfished areas relative to the fished areas with time following protection. The significance of these patterns were tested by a t-test of the difference between means of change through time between fished and unfished areas, calculated as the average of the last two years minus the average of the first two years. All tests other than the first for all large fishes revealed significant differences, returning p values of 0.078, 0.022, 0.023, 0.0020 & 0.012 respectively as two-tailed tests. When this trend was examined as a Pearson product moment correlation coefficient of increase through time, all fished combinations returned non-significant values, whereas the unfished areas all returned values exceeding the critical values required for evidence of a significant relationship with $p < 0.05$, 0.05, 0.05, 0.01 & 0.05 respectively. Overall, large fish appear to be responding to protection within the current sanctuaries. The statistical significance of this was greatest when examined as potential site-attached resident target species only, however it was also significant when *C. fuscus* was removed, indicating that while this species certainly made a major contribution to the increase in large fish through time, other species were also involved. Between the time periods examined, the numbers of all large fish increased by an average of 99%, and the numbers of resident target species increased by an average of 91%. Of the latter, *C. fuscus* contributed an estimated 47%.

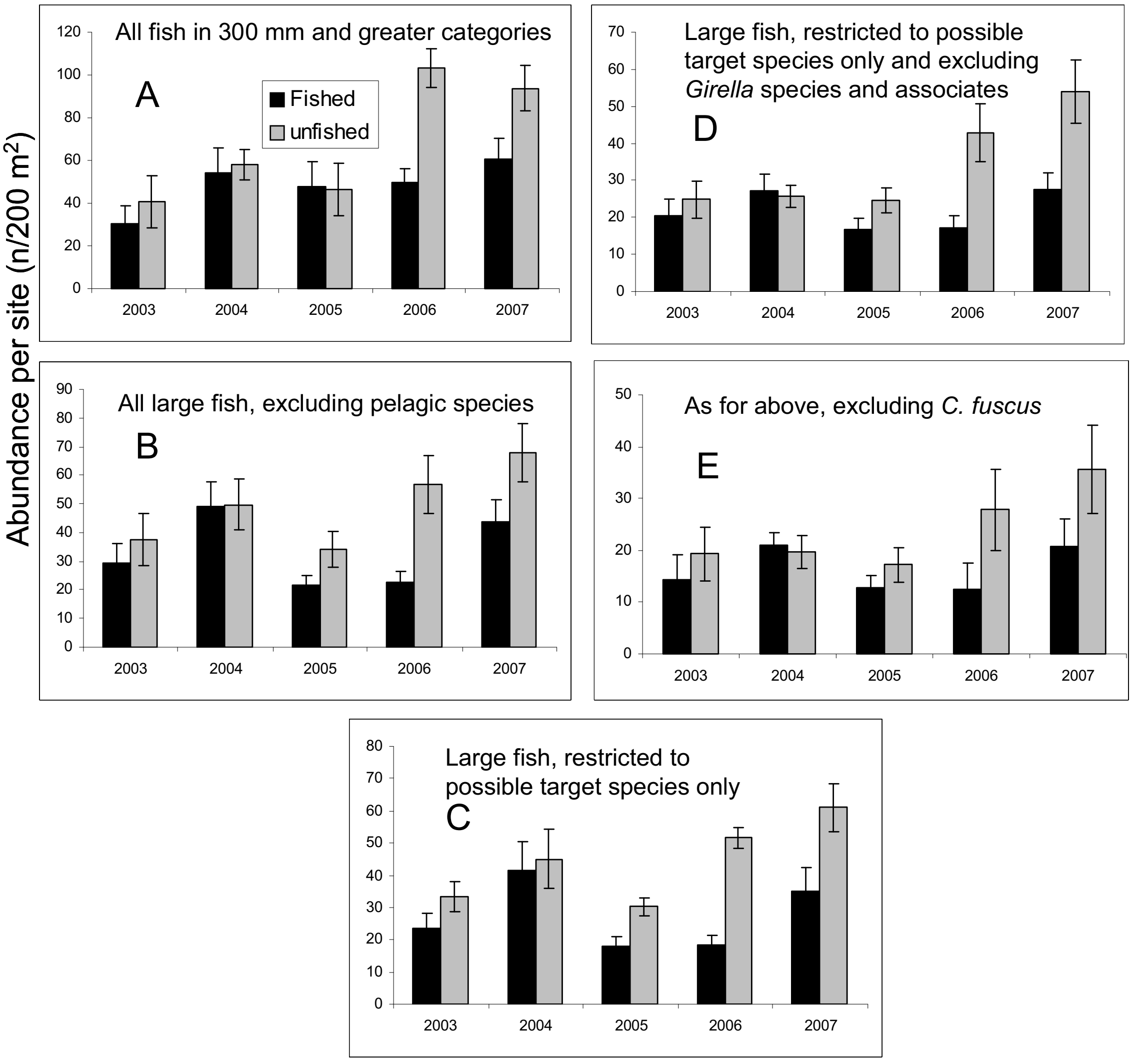

Figure 6. Numbers of larger fishes (300 mm estimated length or larger) in differing size-related groupings within the Jervis Bay MPA during surveys undertaken between 2003 and 2007.

3.2 Invertebrates and cryptic fishes

The most common large mobile invertebrates at JBMP were the sea urchins *Centrostephanus rodgersii* (long-spine urchin), *Heliocidaris erythrogramma* (purple urchin) and *Phyllacanthus parvispinus* (eastern pencil urchin), and the mollusc *Turbo torquatus* (periwinkle) (Appendix 2, Figs 8 & 9). The mollusc *Astraea (Astralium) tentoriformis* (turban shell) was also very abundant but has only been included on surveys since 2003. The sessile solitary ascidian *Herdmania grandis* (red-throat ascidian) was also abundant at many sites. Sessile invertebrates are not normally counted during macro-invertebrate transects in other MPA locations studied by the authors, however *Herdmania* was present in significant numbers at Jervis Bay and is presumably ecologically significant there. None of the cryptic fishes were regularly encountered. Densities of invertebrate and cryptic fish species at each site are shown in Appendix 2 for 2007.

Trends in abundance for a range of invertebrate species were examined using repeated measures ANOVA to see if any significant patterns had arisen after 4 years of protection (Table 3). No significant patterns were detected, and although *Turbo torquatus* came close (P= 0.055), any emerging treatment related pattern there is swamped by the substantial decline in abundance of this species within both sanctuary and fished zones over the duration of the study (Figs 8 & 9).

Centrostephanus dominated the mobile invertebrate fauna at JBMP. This species exhibited no clear distributional pattern of abundance, with large numbers recorded from sites throughout the Bay and on the open coastline (Figs. 8 & 9). *Centrostephanus* numbers show a trend for decline since 2000. At many sites *Centrostephanus* was present in sufficient numbers to form extensive barren zones devoid of algae. These barrens have consistently covered between 40 and 60 percent of the reef in both the sanctuary and non-sanctuary zones (Fig. 13).

The significant decline in *Turbo torquatus* numbers was matched by similar (but not as large) declines in other invertebrate species (Figs 8 & 9). *Herdmania grandis* has declined by approximately 50% over this period and *Astralium and Astrea* species (combined) have declined by a similar magnitude.

This substantial change in the abundance of common invertebrates through time was reflected in the highly directional nature of change evident in the MDS plot of changes in invertebrate assemblage relationships over the past four years (Fig. 7). While the plot does not show the magnitude of changes in the fished sites, the changes were generally similar across zones, and an ANOSIM of this data indicated that the directional change is not likely to be related to levels of protection. A SIMPER analysis of the primary species associated with differences between years indicated that *T. torquatus*, *Astralium* (*Astrea*) species and *Herdmania grandis* contributed to much of the differences detected.

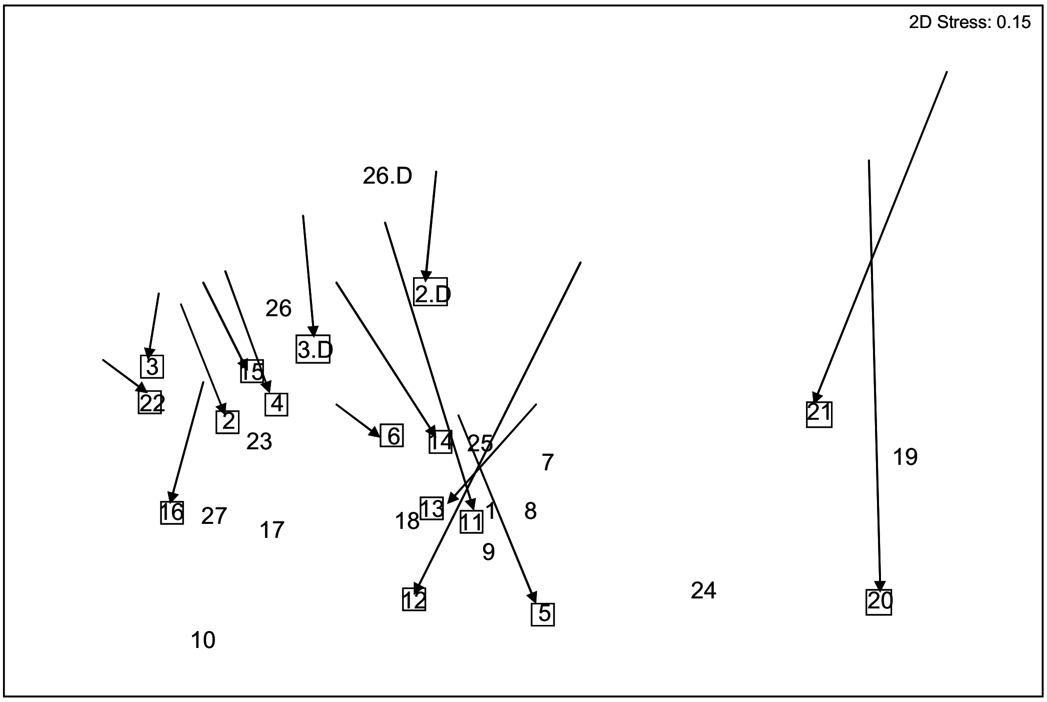

Figure 7. Two-dimensional MDS plot showing the relationship between sites based on 2007 invertebrate and cryptic fish assemblage data. Arrows show change from 2003 (pre reserve) to 2007 for sites located in sanctuary zones. Sanctuary sites are positioned in a square. Sites at 10 m are shown with a "D" suffix.

Table 3. Results of repeated measures ANOVA's (fixed factors year and zone) using annual invertebrate and cryptic fish data for the period 2003 to 2007 from the 27 sites surveyed at Jervis Bay.

Source	SS	df	MS	F	P	Source	SS	df	MS	F	P
Astraea tentoriiformis						*Pentagonaster dubeni*					
ZONE	15.49	1	15.49	3.73	0.064	Zone	0.14	1	0.14	0.25	0.615
Error	116.26	28	4.15			Error	15.77	28	0.56		
Year	1.46	4	0.36	1.42	0.23	Year	0.6	4	0.15	1.16	0.33
Year*Zone	0.66	4	0.16	0.65	0.627	Year*Zone	0.54	4	0.13	1.03	0.394
Error	28.75	112	0.25			Error	14.90	112	0.13		
Heliocidaris erythrogramma						*Phyllacanthus parvispinus*					
Zone	3.73	1	3.73	0.35	0.556	Zone	1.52	1	1.52	0.695	0.411
Error	294.26	28	10.5			Error	61.55	28	2.19		
Year	9.24	4	2.31	3.04	0.02	Year	4.59	4	1.14	2.6	0.035
Year*Zone	4.34	4	1.08	1.43	0.228	Year*Zone	1.77	4	0.44	1.03	0.392
Error	85.02	112	0.75			Error	47.99	112	0.42		
Centrostephanus rodgersii						*Turbo torquatus*					
Zone	37.90	1	37.90	3.05	0.091	Zone	3.0	1	3.0	0.58	0.451
Error	347.42	28	12.40			Error	143.97	28	5.14		
Year	0.64	4	0.16	0.37	0.828	Year	15.48	4	3.87	5.98	0
Year*Zone	0.83	4	0.20	0.48	0.747	Year*Zone	6.19	4	1.5	2.39	0.055
Error	48.35	112	0.43			Error	72.45	112	0.64		
Herdmania grandis											
Zone	21.83	1	21.83	1.65	0.209						
Error	370.2	28	13.22								
Year	0.33	4	0.08	0.12	0.973						
Year*Zone	0.54	4	0.13	0.20	0.936						
Error	75.21	112	0.67								

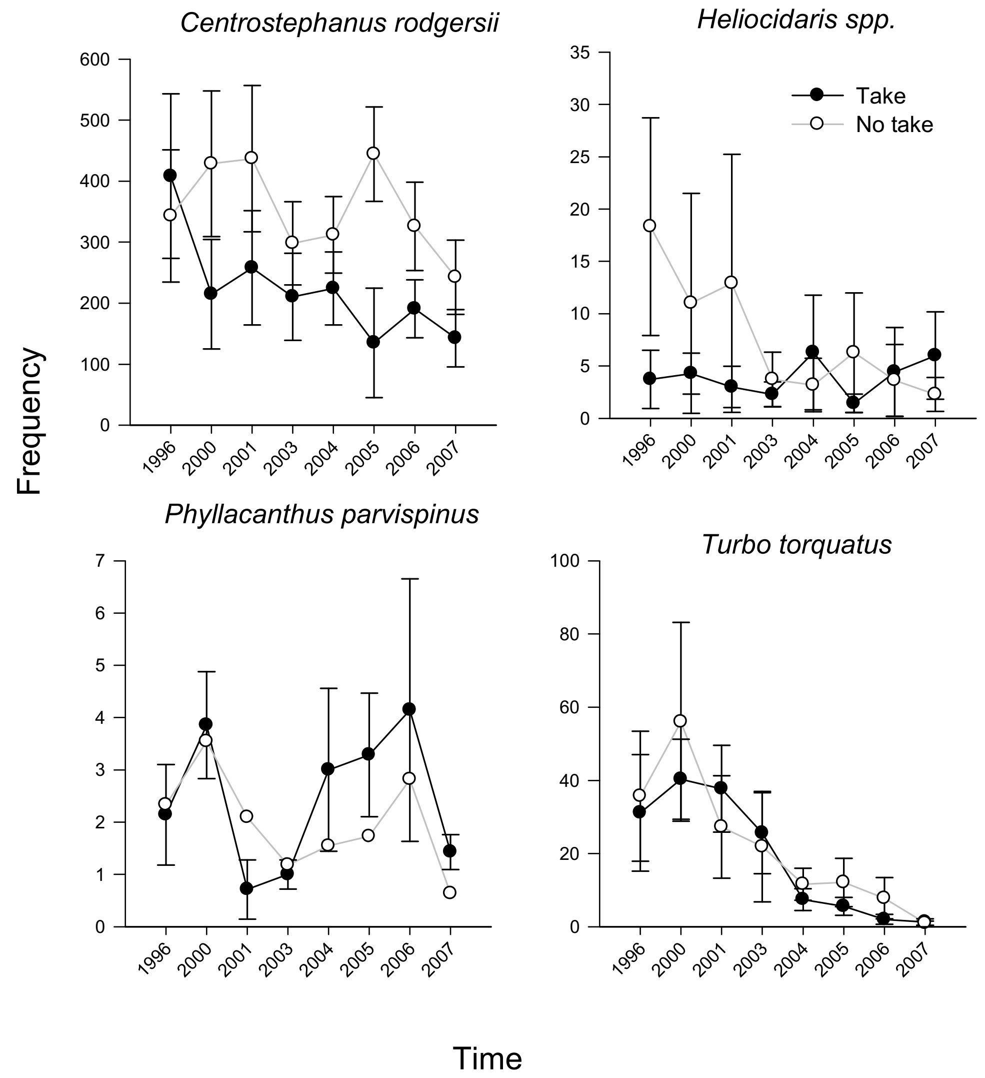

Figure 7. Inter-annual variation in the mean per site abundance of common invertebrates censused during surveys at sites 1 to 18 in 1996, 2000, 2001, 2003, 2004, 2005, 2006 and 2007 at 5m depth contour. (note sites 2 and 3 are excluded in 1996 as they were only conducted at 10m depth)

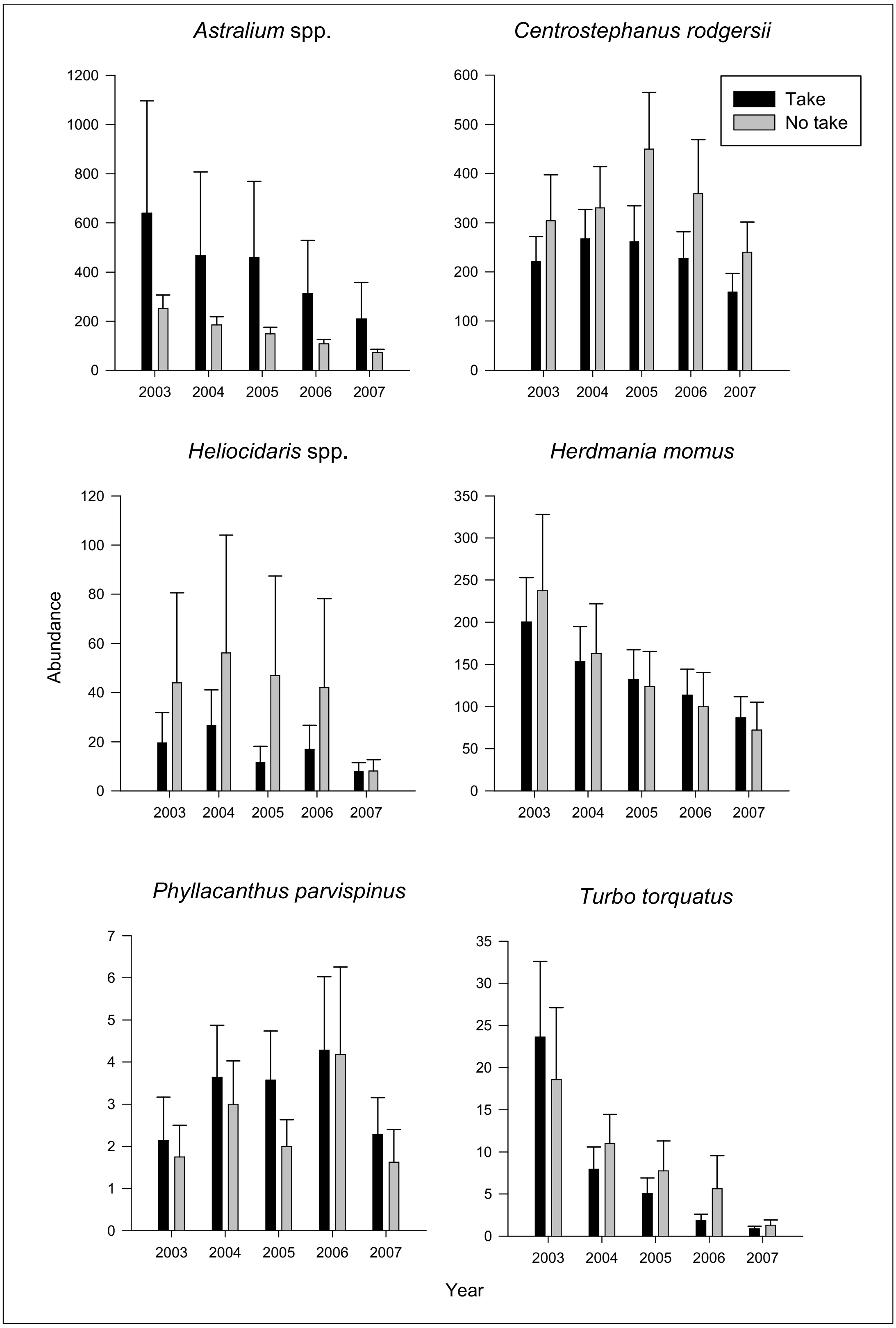

Figure 9. Between treatment variation in the mean per site abundance of common invertebrates censused during surveys at sites 1 to 27 in 2003, 2004 and 2005.

4. Algae

Macroalgae encountered during surveys at JBMP consisted of a relatively low diversity assemblage dominated by brown algae. *Ecklonia radiata* was the dominant cover-forming species at most sites, with *Lobophora variegata* forming a large component of the understorey associated with *Ecklonia*. Species of *Sargassum* contributed a significant component of the cover at Greenpatch and Murrays Beach. Percentage cover of macroalgae at each site is shown in Appendix 3 for 2007.

At site 5 (Blue Hole), the green alga *Caulerpa flexilis* formed a dominant component of the flora, possibly due to the more sheltered nature of this location and the proximity of the transect at 5 m to the sand edge. At site 10 (Longnose Point) geniculate coralline red algae were a major component of the flora, possibly in response to the combination of wave exposure and urchin grazing found at this site. There is a strong negative correlation between algal cover and the abundance of the urchin *Centrostephanus rodgersii* within Jervis Bay (Barrett *et al.* 2002) and it is likely that the overall abundance of urchins at sites strongly influences the assemblage of algal species found there (Andrew and O'Neil 2000; Andrew and Underwood 1993).

The MDS plot of macroalgae assemblages (Fig. 10) shows a high degree of variability between years. This appears to be associated with the low algal diversity found within the study area, coupled with the extensive occurrence of urchin barrens. Small changes in the abundance of the few species present therefore produce a magnified response to change relative to more diverse assemblages such as the fish of macroinvertebrates. Stress associated with the plot was relatively high indicating that the depiction was towards the end of the acceptable range for 2D plotting.

Trends in abundance for a range of algal species and other species groupings estimated by the quadrat method were examined using repeated measures ANOVA to see if any significant patterns had arisen after 4 years of protection (Table 4). No significant patterns were detected for algal species, and although the encrusting coral *Plesiastrea versipora* did show a significant year x zone interraction (P= 0.018), an examination of the data (Appendix 3) suggests that this result is a chance variation in the detected abundance of a species encountered at low levels.

Further examination of the algal data was limited to *Ecklonia radiata* and *Sargassum* spp. as the remaining species were either rare or restricted to a small number of sites. Figs 11 and 12 indicate that the cover of both *Ecklonia* and *Sargassum* is relatively similar between zones and has shown only slight variation over time. Furthermore changes to algae communities are likely to take a greater length of time to detect as it will likely result from a flow on effect from changes to herbivore densities.

Urchins, particularly *Centrostephanus rodgersii,* significantly alter the algal cover within the JBMP and result in between 40-60% of the seabed within our survey sites being denuded of algae (Fig. 13), and this heavy grazing pressure clearly influences patterns of local algal biodiversity.

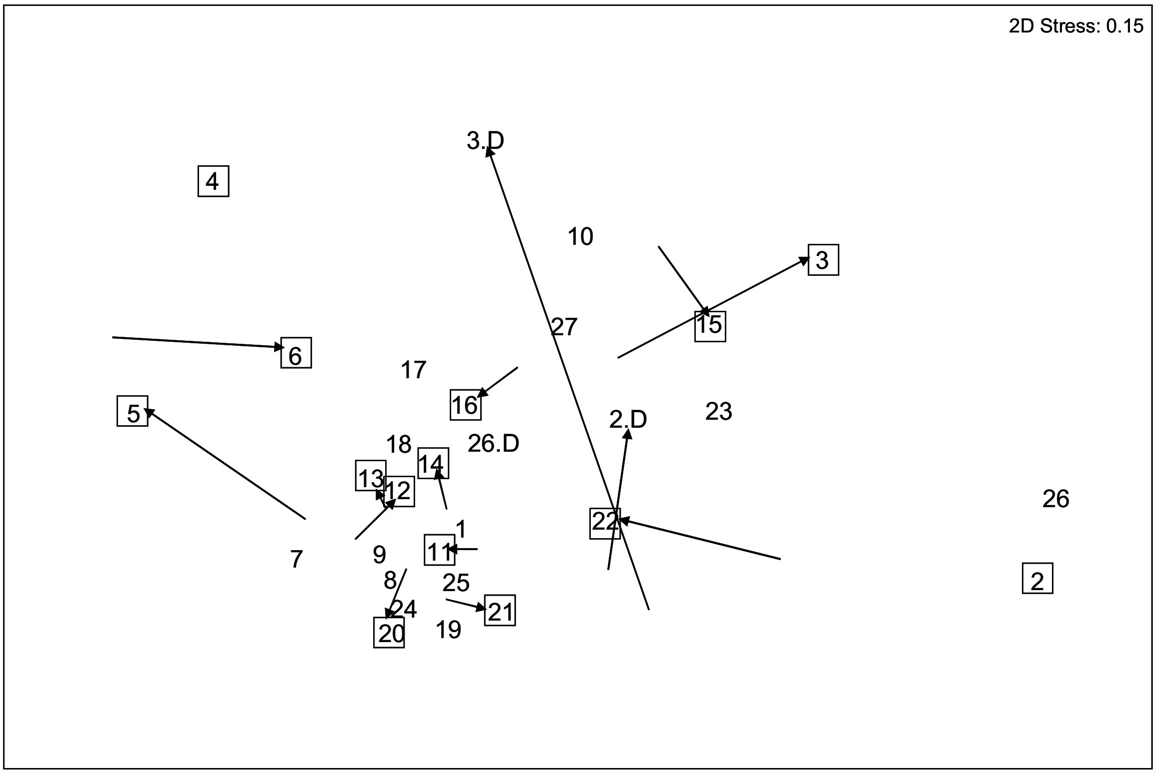

Figure 10. Two-dimensional MDS plot showing the relationship between sites based on 2007 algae assemblage data. Arrows show change from 2003 (pre reserve) to 2007 for sites located in sanctuary zones. Sanctuary sites are positioned in a square. Sites at 10 m are shown with an "D" suffix.

Table 4. Results of repeated measure ANOVA's (fixed factors year and zone) using results from algae data for five years from 2003 to 2007 for the 27 sites surveyed at Jervis Bay.

Source	SS	df	MS	F	P	Source	SS	df	MS	F	P
Sargassum species						*Herdmania grandis*					
ZONE	0.003	1	0.003	0.001	0.979	ZONE	4.072	1	4.072	2.627	0.116
Error	124.9	28	4.461			Error	43.4	28	1.55		
a	1.67	4	0.418	1.416	0.233	a	0.141	4	0.035	0.363	0.835
a*ZONE	1.19	4	0.3	1.016	0.402	a*ZONE	0.157	4	0.039	0.403	0.806
Error	33.03	112	0.295			Error	10.89	112	0.097		
Ecklonia radiata						*Plesiastrea versipora*					
ZONE	61.15	1	61.15	9.717	0.004	ZONE	0.211	1	0.211	0.214	0.647
Error	176.2	28	6.294			Error	27.63	28	0.987		
a	1.28	4	0.321	0.771	0.546	a	2.886	4	0.722	3.106	0.018
a*ZONE	0.83	4	0.209	0.502	0.735	a*ZONE	2.882	4	0.72	3.101	0.018
Error	46.60	112	0.416			Error	26.0	112	0.232		
Lobophora variegata						Sponge cover					
ZONE	6.75	1	6.757	2.167	0.152	ZONE	3.938	1	3.938	2.14	0.155
Error	87.3	28	3.119			Error	51.52	28	1.84		
a	1.19	4	0.299	1.159	0.333	a	5.564	4	1.391	7.654	0
a*ZONE	1.03	4	0.259	1.001	0.41	a*ZONE	0.727	4	0.182	0.999	0.411
Error	28.92	112	0.258			Error	20.35	112	0.182		

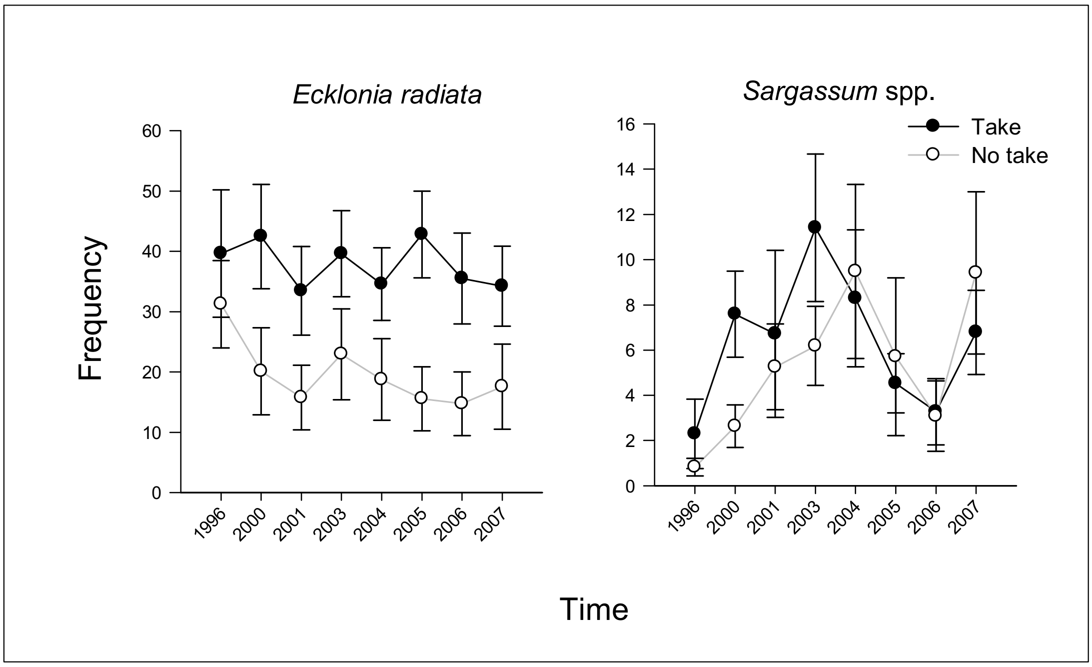

Figure 11. Inter-annual variation in the mean abundance (percentage cover) per site of common algae censused during surveys at sites 1 to 18 in 1996, 2000, 2001, 2003, 2004, 2005, 2006 and 2007 at 5m depth contour. (note sites 2 and 3 are excluded in 1996 as they were only conducted at 10m depth)

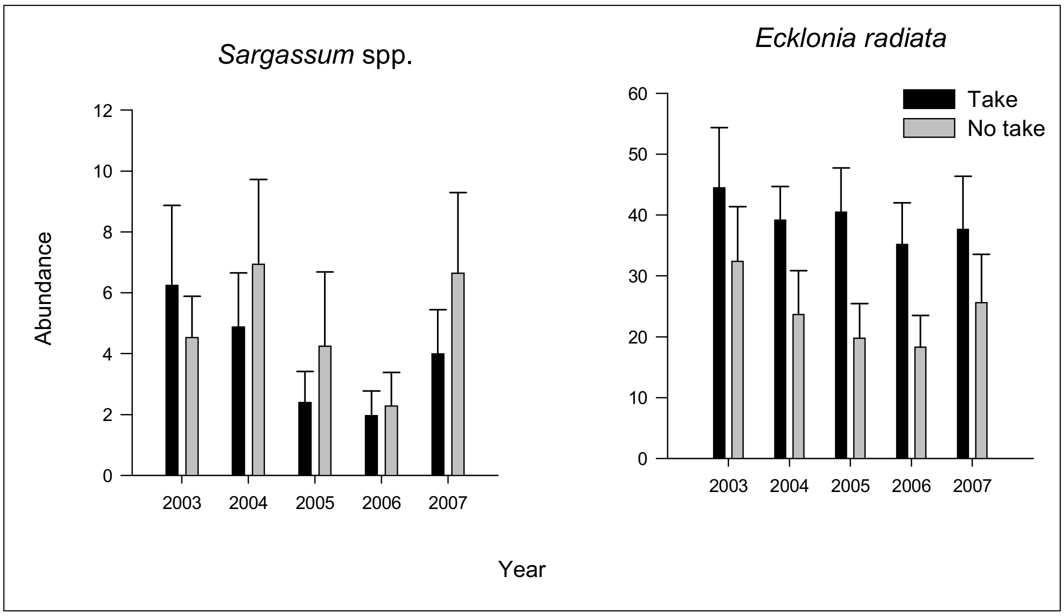

Figure 12. Between treatment variation in the abundance (percentage cover) of common algae censused during surveys at sites 1 to 27 in 2003, to 2007.

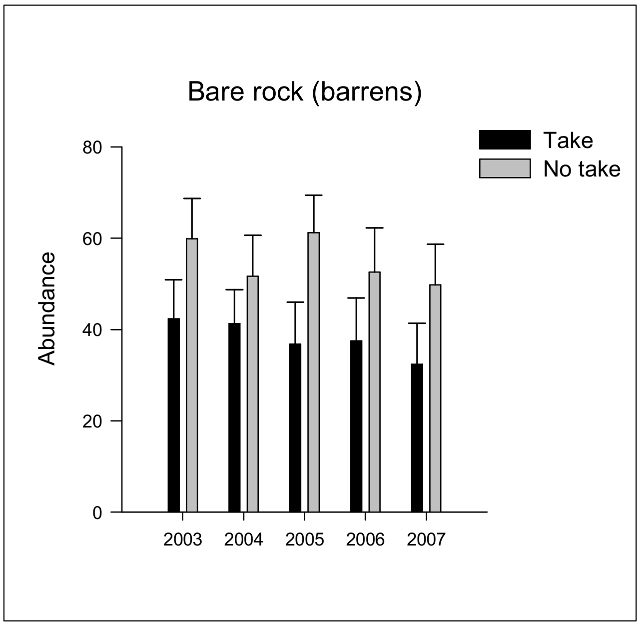

Figure 13. Relative abundance (%) of bare rock to algal covered rock resulting from grazing of the urchin *Centrostephanus rodgersii* at sites 1 to 27 from 2003 to 2007.

5. Discussion

Our surveys provide a broad-scale description of the resident reef fishes, large mobile invertebrates and cover-forming plants and animals of the inshore reefs within the Jervis Bay component of the Jervis Bay Marine Park (JBMP). This report builds upon, and includes, the results of previous surveys undertaken as part of this study (Barrett *et al.* 2002, 2006). The results show that many of the more common species surveyed displayed relatively stable population structures over time, with major exceptions being schooling or pelagic fish species and tropical fish recruits that all show a high degree of variability.

The most notable trends to become apparent by 2007 were a significant increase in *Cheilodactylus fuscus* (red morwong), large fish (300 mm length or greater) in sanctuary zones relative to fished zones, and a marked system wide decline in the abundance of several common invertebrates, including *Turbo undulates* (wavy turbo), *Astralium* and *Astrea* gastropods and *Herdmania grandis* (red-throated ascidean). The increase in *C. fuscus* numbers was closely matched by a substantial change in its size distribution within sanctuary zones, with individuals in larger size categories increasing notably relative to fished zones. This change is presumably related to high exploitation levels for the reef associated *C. fuscus*, and the resident nature of this species (Schroeder *et al.* 1994). This change was not matched by a similar pattern with any other exploited species or site based species richness. While *Acanthopagrus australis* (yellow-fin bream) showed a weakly statistically significant trend in our last analysis (Barrett *et al.* 2006), and *Chrysophyrus auratus* (snapper) showed a similar trend in this analysis, both species had declined to such low numbers in the 2007 surveys that any trends should be treated with caution. Clearly if species such as snapper are to recover in sanctuary zones within JBMP in a similar manner to that found in comparable habitats in New Zealand (Willis *et al.* 2001), this process may rely on infrequent strong recruitment events, as evident for *Latridopsis forsteri* in Tasmanian MPAs (Barrett *et al.* 2007), rather than a gradual accumulation of individuals through time.

Overall, large fish increased significantly within sanctuary zones regardless of whether the whole fish assemblage was included or the analysis restricted to only target resident species. Interestingly, while *C. fuscus* accounted for some of the observed increase, more than 50% of this was attributable to other species that, when examined alone, were not sufficiently abundant to show significant trends.

While changes resulting from the first four years of protection were primarily restricted to *C. fuscus* and the broader large fish category, this pattern is consistent with other MPA research that indicates that ecological changes after fishing closures take a minimum of 2 and 4 years to detect (Carter and Sedberry 1997 in Ward *et al.* 2001). Ward *et al.* (2001) suggest that density differences are maximised between 6 and 8 years following protection and that monitoring should continue for at least ten years. This time scale should be sufficient for species that have either pulse or episodic recruitment events to settle and establish, and should also be long enough to account for variation between recruitment years. It would also allow time for exploited species to grow sufficiently to be detected in size category analysis, and for the larger size categories to reflect storage of longer lived species as growth slows.

One final observation of some note with respect to changes following protection was the increasing occurrence of grey nurse sharks in one of the Sanctuary zones (The Docks). In this zone, juvenile sharks were observed in 2004 and 2005 for the first time, and nine of these were counted on transects there in 2006. These sharks had disappeared by the 2007 survey, with anecdotal evidence from local dive operators suggesting this was related to particularly cold water temperatures during the previous summer. The site includes a large overhanging cave feature that the sharks reside in during the day, and presumably this physical feature contributes to the localised nature of the aggregation. These observations suggest that small sharks may often recruit to this site but in the past were fished out each year during the main summer fishing season (Lynch *et al.* 2004), immediately prior to our UVC surveys. However, a longer time series will be needed to determine the strength of this pattern, particularly as the population was absent during the 2007 survey.

Clearly larger scale ecosystem changes are influencing parts of the assemblage present within the JBMP, particularly the macroinvertebrate component. The strong declines in *T. torquatus* and the *Astralium* and *Astrea* gastropods was matched by weaker but still directional declines in *Herdmania grandis, Heliocidaris* species and *C. rodgersii* over the past few years, resulting in a significant directional shift when the combined assemblage change was examined by multivariate techniques (MDS). Inter-annual recruitment variability has presumably played an important role in this emerging pattern as the trends are independent of levels of protection. Our results highlight the importance of having a long-term dataset from which to understand these patterns, and the typical magnitude of natural variability that lies behind the biological patterns observed following MPA establishment. Such information is needed to clearly identify protection related effects.

Although of particular interest as resource species, abalone and rock lobster were extremely rare at the sites and depths surveyed. For lobsters, this suggests recruitment of juveniles to the area is extremely low, possibly due to the depletion of the overall population in southern NSW waters and an associated decline in reproductive output. Any recovery within the JBMP is therefore likely to be a slow process that is linked to recovery of the overall stock.

Similarly, recovery of abalone is also likely to take a considerable time. Abalone larvae disperse poorly and therefore tend to recruit mostly within their home reef. They also need a critical mass of individuals at any one site for successful spawning, and currently this appears to be absent from the sites surveyed within the park. The extensive cover of urchin barrens in JBMP appears to restrict available habitat to shallow water (0-2 m depth) above the barren zone, in a depth range not covered by this study.

The type and magnitude of ecosystem shifts following protection from fishing is difficult to predict for the JBMP. It is anticipated that closures to fishing will eventually result in a shift in abundance in some species. This will not necessarily correspond to an increase in abundance for all species in the sanctuary zones. For example some species may survive better in fished areas as they experience less predation pressure. Similarly, some territorial fish species may increase in size which may lead to larger territories for individual animals and an overall reduction in density.

The most likely scenario for the JBMP involves the sea urchin *Centrostephanus rodgersii,* a species that is presently highly abundant within the bay, and which forms large barren zones (Andrew 1991). Where barrens are not evident, this species may still substantially affect algal and invertebrate assemblage present, and, by modifying the habitat, indirectly influence fish assemblages. Following protection from fishing, the abundance and size of fish that prey on *Centrostephanus* may increase to a point where they reduce the abundance of this species to levels that allow algal cover to re-establish, and algal diversity to increase, with subsequent effects on fish and invertebrate assemblages (Babcock *et al.* 1999). Although no such effect is so far indicated, the current experimental design should detect any such community shifts, including increases in abundance and size of key urchin predators, decline in urchin abundance, increase in algal cover and diversity, and other indirect changes to fish and invertebrate assemblages. Thus, the broadly-based monitoring design is well matched with the first objective of the NSW MPA Act, which is to conserve marine biodiversity (MPA, 1997).

The selection of over 12 sites within each treatment should be sufficient to detect biologically meaningful change within the species examined. From the results of the Tasmanian MPA study (Edgar and Barrett 1997, 1999) and a workshop examining MPA monitoring techniques (Barrett & Buxton 2002), it appears that where the abundance of each species is adequately described at each site, six sites would be the accepted minimum number of "replicates" per treatment for an effective monitoring program. The current results indicate that the abundances of many species are described adequately; however for fishes, particularly some schooling species that are mobile and move within or between reefs, additional replication would be beneficial for reducing between year variance.

Continuing surveys at annual intervals are highly recommended to establish time series data and to allow trends through time to be differentiated from chance fluctuations. Once trends in abundance of key species stabilise, then the frequency of monitoring can decrease. In the present JBMP dataset we now have data for eight years (if the reduced site replication for 1996, 2000 & 2001 is included). We suggest that an additional full survey be undertaken in 2008 to extend that to a nine year time series and an annual series of almost five years since full protection of the MPA.

Because the overall rate of change within the sanctuary zones in JBPB following protection appears to be slow, ongoing studies at intervals longer than one year may provide a cost-effective way to follow protection effects in this Marine Park. Nevertheless, the reef monitoring program generates benefits additional to assessment of marine park effectiveness, including tracking future impacts of climate change and invasive species. These additional benefits may warrant the continuance of annual monitoring in the JBMP.

Clearly the significant decline of common macroinvertebrates in the region highlights the merits of long term data in understanding change more widely. As changes in cover of macroalgae are predicted to take considerably longer to express themselves than changes in populations of fishes and invertebrates, we recommend that if a reduced budget is available through the long term and monitoring continues, then assessment of macroalgae be omitted in some years, rather than reducing the number of sites investigated for fishes and macroinvertebrates.

With respect to the management review of JBMP as it approaches five years of protection, it is clear that site attached reef species such as red morwong do benefit from protection within the current zoning arrangements, particularly with respect to protection of larger fishes. So too, do species such as grey nurse sharks which have a temporary attachment to particular physical features of the reef habitat. By contrast, species such as bream and snapper that range across habitats are not recovering to the same extent as in New Zealand studies in similar habitat types (e.g. Willis *et al.* 2001, 2003). This outcome is possibly due to the JBMP zones being smaller than fish movement patterns, but also possibly that insufficient time has passed for adult populations to accumulate in the Park. While there are no clear actions that could be taken to improve recovery of such species at this stage, additional research focussed on movement patterns could examine habitat use and connectivity within the bay for key species to ensure optimal protection is eventually available.

We make few specific recommendations at this early stage of the JBMPA monitoring program:

(1) the grey nurse shark aggregation site at The Docks should be managed to minimise disturbance through dive tourism, including regulation of visitation rates and a diving code of conduct to minimise adverse interactions affecting the sharks;

(2) where possible any similar known historical aggregation sites of grey nurse sharks be given a similar level of protection (including sanctuary zoning);

(3) fishing from boats be disallowed in the narrow coastal shore fishing zone adjacent to Hyams Beach. This recommendation is based on observations that juvenile snapper are frequently observed adjacent to the reef in this area. Population

recovery is potentially compromised by boating access which provides the opportunity to target an adjacent reef system reef and associated habitats, which are unavailable to shore based fishermen. Recommendations relating to ongoing studies/monitoring are discussed in the previous section.

6. Acknowledgments

We would like to acknowledge the assistance given by the NSW Marine Parks Authority and Jervis Bay Marine Park in establishing and continuing these surveys, including management support from Leigh Harris and Alan Jordan. MPA-JBMP contributed staff (Ian Osterloh, Mark Fackerell and Sue Brown), vessels, and logistic support essential for undertaking this research. ARC provided complementary funding for TAFI staff. We would also like to thank staff of Booderee National Park and HMAS Creswell for their invaluable contributions to the project.

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Appendix 1. Fish abundances recorded during surveys conducted at Jervis Bay in May 2006.

Species	Depth Common name/site	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9	5 10	5 11	5 12	5 13	5 14	5 15	5 16	5 17	5 18	5 19	5 20	5 21	5 22	5 23	5 24	5 25	5 26	5 27	5 30	10 2	10 3	10 26	Total
Abudefduf vaigiensis	Sergeant major	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
Acanthaluteres vittiger	Toothbrush leatherjacket	2	0	0	0	0	0	5	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	16
Acanthapagrus australis	Yellowfin bream	0	0	2	6	32	0	0	0	3	3	33	0	0	8	3	2	5	11	0	0	0	0	0	6	0	0	270	0	0	2	0	386
Acanthistius ocellatus	Eastern wirrah	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
Achoerodus viridis	Eastern blue groper	10	3	27	8	20	10	11	7	96	34	53	33	30	23	13	5	12	9	2	26	1	3	3	7	10	9	37	0	13	12	11	538
Anoplocapros inermis	Eastern smooth boxfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Apogon limenus	Sydney cardinalfish	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Aptychotrema rostrata	Long-snout shovelnose ray	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Arripis spp.	Australian salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400	0	400
Aspidontus taeniatus	False cleanerfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Asymbolis analis	Spotted Catshark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Atypichthys strigatus	Mado sweep	1169	175	210	385	199	75	117	429	264	274	232	1761	1115	150	936	307	752	1065	1731	1354	220	845	899	979	596	363	464	0	465	64	2310	19905
Aulopus purpurissatus	Sergeant baker	0	0	1	0	2	0	0	0	0	0	0	2	0	0	2	0	0	1	0	0	0	0	2	0	0	0	0	0	2	0	2	14
Austrolabrus maculatus	Black-spotted wrasse	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	1	0	5	0	4	0	0	0	0	0	0	0	0	2	0	16
Brachaluteres jacksonianus	Pygmy leatherjacket	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3
Caesioperca rasor	Barber perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5
Canthigaster callisterna	Clown toby	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	7
Carcharius taurus	Grey Nurse Shark	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Chaetodon guntheri	Gunthers butterflyfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Cheilodactylus fuscus	Red morwong	23	11	28	5	79	16	16	13	51	10	76	36	66	80	19	42	22	36	2	16	5	0	3	13	22	7	24	0	15	37	8	781
Cheilodactylus spectabilis	Banded morwong	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cheilodactylus vestitus	Crested morwong	0	0	0	0	1	1	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	10
Chelmonops truncatus	Eastern talma	1	2	1	0	4	4	8	8	14	3	0	10	14	2	4	3	2	8	0	10	1	0	0	3	8	0	6	0	1	0	6	123
Chelonia mydas	Green Turtle	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chironemus marmoratus	Kelpfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	17	1	1	0	1	0	0	0	0	22
Chromis hypsilepis	One-spot puller	0	848	427	1508	0	34	0	0	0	416	0	0	0	0	927	247	2	3	0	0	0	988	4352	0	0	1775	57	0	529	1650	410	14173
Pagrus auratus	Snapper	2	0	2	5	19	2	0	0	12	0	9	1	0	10	1	0	51	10	0	0	3	0	0	0	0	0	0	0	0	8	0	135
Cnidoglanis macrocephalus	Estuary catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	4
Coris picta	Comb wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	1	0	0	0	0	0	0	1	1	0	7
Coris sandageri	King wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Crinodus lophodon	Rock cale	0	10	62	10	5	2	6	3	13	42	18	6	28	7	11	25	2	4	1	3	0	17	4	6	5	22	40	0	1	9	14	376
Dactylophora nigricans	Dusky morwong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Dasyatis brevicaudata	Smooth stingray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Dasyatis thetidis	Black stingray	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4
Dicotylichthys punctulatus	Three-bar porcupinefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3
Dinolestes lewini	Long-fin pike	10	10	3	6	25	4	53	0	1	0	126	27	204	197	18	0	47	62	0	0	1	2	7	12	3	14	6	0	4	201	91	1134
Diodon nicthemerus	Globe fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
Dotalabrus aurantiacus	Castelnau's wrasse	0	0	0	0	1	2	3	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	10
Enoplosus armatus	Old wife	6	30	16	5	54	2	94	137	9	5	36	2	108	19	65	32	2	118	0	760	1	3	9	10	218	9	13	0	23	39	20	1845
Eubalichthys bucephalus	Black reef-leatherjacket	1	1	1	2	9	0	0	1	1	3	0	2	0	1	1	0	17	0	0	0	0	0	4	0	1	2	4	0	8	5	2	66
Eubalichthys mosaicus	Mosaic leatherjacket	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7
Eupetrichthys angustipes	Snake-skin wrasse	0	0	0	0	3	9	4	0	0	0	0	2	1	0	3	5	2	2	0	2	0	0	0	0	1	0	0	0	1	1	0	36
Gerres subfasciatus	Common silver belly	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	8
Girella elevata	Rock blackfish	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	8
Girella tricuspidata	Luderick	0	0	16	0	0	0	0	0	0	12	1	0	0	9	222	130	0	0	0	0	0	3	11	0	0	1	2	0	0	1	0	408
Girella zebra	Zebra fish	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gymnothorax prasinus	Green moray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Halichoeres nebulosus	Clouded wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Heniochus acuminatus	Longfin Bannerfish	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Heterodontus portusjacksoni	Port Jackson shark	0	0	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	9
Hypoplectrodes annulatus	Black-banded seaperch	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
Hypoplectrodes maccullochi	Half-banded seaperch	1	8	3	12	2	11	0	3	2	4	3	0	2	0	6	2	1	0	1	0	0	3	2	1	1	9	3	0	12	0	10	102
Hypoplectrodes nigroruber	Banded seaperch	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Hyporhamphus australis	Eastern garfish	0	0	0	0	0	350	0	0	0	0	0	320	0	0	0	350	0	0	0	0	0	600	100	0	0	0	0	0	0	0	0	1720
Kyphosus sydneyanus	Silver drummer	0	1	79	6	0	0	0	0	0	12	0	0	0	0	40	2	0	1	0	0	0	7	2	0	0	3	1	0	0	3	0	157
Labroides dimidiatus	Cleaner wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Leptojulis cyanopleura	Blue-spot wrasse	0	0	0	3	0	4	0	0	0	0	0	0	0	0	3	7	6	1	0	0	0	3	0	0	0	1	0	0	0	0	0	28
Lotella rhacina	Beardie	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	4
Mecaenichthys immaculatus	Immaculate damsel	7	8	0	3	9	7	7	3	8	0	0	8	9	6	1	2	13	21	0	1	0	0	0	0	0	1	0	0	3	0	2	119
Meuschenia australis	Brown-striped leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Meuschenia flavolineata	Yellow-stripe leatherjacket	0	2	6	4	1	0	0	1	0	3	0	9	0	0	0	0	0	0	0	0	0	2	0	0	0	0	18	0	16	12	16	90
Meuschenia freycineti	Six-spine leatherjacket	0	5	24	0	3	0	0	1	0	1	0	2	2	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	5	6	1	53
Meuschenia trachylepis	Yellow-finned leatherjacket	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
Meuschenia venusta	Stars and stripes leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4
Microcanthus strigatus	Stripey	0	5	5	17	0	0	0	0	0	0	1	0	0	2	0	2	0	1	0	0	0	0	0	2	1	2	0	0	0	10	22	70
Monacanthus chinensis	Fan-bellied Leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Monodactylus argenteus	Silver batfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Nelusetta ayraudi	Chinaman leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	1	29	0	0	0	2	0	0	0	0	0	0	0	0	0	19	80
Nemadactylus douglasi	Blue morwong	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0	0	0	0	0	0	0	0	0	4	9	0	35
Neoodax balteatus	Little rock whiting	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
New bovichthyid	Dragonet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	5
Notolabrus gymnogenis	Crimson-banded wrasse	17	13	15	43	87	41	41	11	21	11	25	42	90	35	5	17	25	18	3	10	126	4	5	22	18	6	24	0	10	22	22	829
Odax acroptilus	Rainbow cale	1	0	0	1	3	1	3	0	7	0	1	4	0	0	0	1	2	2	0	0	1	0	0	0	0	0	0	0	0	0	1	28
Odax cyanomelas	Herring cale	8	0	1	2	7	13	33	5	16	0	6	28	29	1	7	6	0	6	7	3	3	1	0	10	74	0	0	0	3	2	12	283
Ophthalmolepis lineolata	Maori wrasse	23	3	4	13	30	37	32	11	23	8	32	24	24	25	11	70	17	27	0	19	9	26	7	2	12	1	6	0	14	17	8	535
Paraplesiops bleekeri	Eastern blue devil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Paraplesiops meleagris	Western blue devil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
Parequula melbournensis	Silverbelly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Parma mccullochi	McCulloch's scalyfin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	9
Parma microlepis	White-ear	23	77	46	61	12	85	36	10	7	46	14	15	21	42	52	44	32	41	1	0	0	9	34	0	30	49	60	0	49	10	52	958
Parma unifasciata	Girdled parma	0	7	7	0	0	2	0	0	0	0	0	0	5	0	4	1	0	0	0	0	0	0	11	0	0	1	30	0	0	0	0	68
Parupeneus signatus	Blackspot goatfish	17	0	4	0	62	0	14	7	0	0	3	17	3	13	1	87	33	58	2	1	1	0	1	0	3	0	6	0	0	5	5	343
Pelates sexlineatus	Eastern striped trumpeter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pempheris affinis	Black-tipped bullseye	26	0	0	15	0	2	0	6	0	0	0	20	36	11	1	0	1	0	0	8	0	0	0	2	3	30	0	0	16	0	59	236
Pempheris compressa	Small-scale bullseye	0	179	441	160	0	5	0	216	13	6	8	347	37	275	54	2	390	116	0	1	0	40	59	46	27	337	287	0	6	640	378	4070
Pempheris multiradiata	Common bullseye	1	0	0	100	0	1	0	6	6	90	4	0	10	20	397	160	0	1	1	0	0	0	0	33	0	0	0	0	65	0	213	1108
Pentaceropsis recurvirostris	Long-snouted boarfish	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Petroscirtes fallax	Yellow Sabretooth Blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pictilabrus laticlavius	Senator wrasse	1	0	0	0	19	10	11	13	9	3	8	12	22	5	1	10	10	6	12	17	6	0	0	11	5	0	0	0	1	0	0	192
Plagiotremus rhinorhynchos	Tube-worm blenny	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Plagiotremus tapeinosoma	Hit and run blenny	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pomacentrus coelestis	Neon damsel	0	1	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	9
Pomatomus saltatrix	Tailor	0	0	0	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250
Prionurus microlepidotus	Sawtail surgeonfish	0	0	0	0	0	0	1	0	4	0	4	0	27	8	2	0	0	5	0	23	0	0	0	5	10	1	3	0	0	0	0	93
Pseudocaranx dentex	White Trevally	0	0	3	23	60	0	0	80	0	0	0	0	50	3	38	52	0	0	0	0	0	0	6	0	9	0	0	0	5	100	0	429
Pseudolabrus guntheri	Gunthers wrasse	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Pseudolabrus luculentus	Luculentus wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Ptereleotris heteroptera	Tail Spot Dart-Goby	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rhabdosargus sarba	Tarwhine	8	0	0	7	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Sarda australis	Australian bonito	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Schuettea scalaripinnis	Eastern pomfret	346	0	0	0	0	0	0	60	492	0	53	0	25	0	258	0	0	18	0	0	0	0	0	0	160	1295	0	0	0	0	2360	5067
Scobinichthys granulatus	Rough leatherjacket	0	0	2	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	9
Scorpaena cardinalis	Red rock cod	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scorpaena papillosa	Southern rockcod	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scorpis lineolata	Silver sweep	16	72	108	3	21	277	0	0	0	39	0	11	85	297	45	0	0	51	47	17	0	0	29	28	331	11	11	0	3	48	3	1553
Sepia apama	Giant cuttle	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	4
Sepioteuthis australis	Southern calamary	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Seriola lalandi	Yellowtail kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10
Squatina australis	Angel shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Stethojulis interrupta	Cut-ribbon wrasse	0	0	0	0	18	0	0	0	0	0	0	0	0	0	6	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Stethojulius bandanensis	Red-spot wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Suezichthys devisi	Gracilis wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
Thalassoma hardwicke	Six-bar wrasse	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	4
Thalassoma lunare	Moon wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Torquigener pleurogramma	Banded toadfish	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	3	0	0	0	0	0	0	3	1	0	0	0	1	14
Trachinops taeniatus	Eastern hulafish	91	2119	1010	1965	114	1329	283	78	47	633	54	360	685	1412	2125	75	50	157	0	3	0	1170	412	35	27	405	1139	0	1520	510	1265	19073
Trachurus novaezelandiae	Yellow-tail scad	217	61	702	455	1716	675	1038	5	931	0	1401	3110	474	207	820	186	0	500	0	0	10	0	0	0	102	1209	77	0	70	1190	1658	16814
Trygonoptera spp1	Banded Stingaree	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Trygonoptera testacea	Common stingaree	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Trygonorrhina fasciata	Fiddler ray	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	6
Unidentified fish	Unidentified fish	0	0	0	0	0	1	0	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Upeneichthys lineatus	Blue-lined goatfish	0	0	0	2	10	6	6	2	1	0	0	0	0	2	2	3	28	7	0	0	9	0	0	0	0	0	0	0	2	1	0	81
Urolophus paucimaculatus	Sparsely spotted stingaree	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Valencienna strigata	Golden-head sleeper-goby	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Xyrichtys dea	Leaf wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Zanclus cornutus	Moorish idol	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5
Species Diversity		**27**	**28**	**34**	**36**	**38**	**37**	**26**	**29**	**31**	**25**	**28**	**32**	**38**	**34**	**53**	**41**	**36**	**43**	**18**	**23**	**22**	**22**	**28**	**23**	**27**	**37**	**28**	**0**	**36**	**36**	**37**	

Appendix 2. Fish abundances recorded during surveys conducted at Jervis Bay in May 2007.

	Depth	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10	10	10	Total
Species	**Common name/site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**30**	**2**	**3**	**26**	
Abudefduf sexfasciatus	Scissor-tail Seargent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Abudefduf vaigiensis	Sergeant major	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	10
Acanthaluteres vittiger	Toothbrush leatherjacket	6	0	0	0	0	1	3	1	2	0	3	1	0	4	0	8	1	2	0	0	0	0	0	2	1	1	0	0	0	0	14	50
Acanthapagrus australis	Yellowfin bream	0	1	0	2	0	0	0	0	1	0	0	0	2	5	0	0	3	8	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Acanthistius ocellatus	Eastern wirrah	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Achoerodus viridis	Eastern blue groper	17	5	10	6	12	2	14	6	8	13	12	13	24	23	17	7	9	6	0	8	3	4	5	2	2	8	21	6	15	1	2	281
Apogon aureus	Ring-tail cardinalfish	0	0	0	3	0	0	0	0	0	0	0	8	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Apogon limenus	Sydney cardinalfish	3	0	0	0	12	2	0	0	4	0	0	7	0	2	1	1	2	5	0	0	0	0	0	0	0	0	0	0	0	1	0	40
Arripis spp.	Australian salmon	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	28
Aspidontus taeniatus	False cleanerfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Atypichthys strigatus	Mado sweep	1749	436	388	384	93	160	964	564	236	1605	269	124	381	260	535	90	17	482	229	110	382	961	1090	272	411	944	597	269	357	175	973	15507
Aulopus purpurissatus	Sergeant baker	0	1	4	3	3	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	3	0	1	4	3	4	30
Austrolabrus maculatus	Black-spotted wrasse	3	0	0	0	5	1	2	4	6	0	1	1	0	2	0	0	0	0	13	4	5	0	0	4	4	0	0	0	0	1	0	56
Bovichtus angustifrons	Dragonet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Brachaluteres jacksonianus	Pygmy leatherjacket	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	5
Caesio caerulaurea	Gold-banded fusailier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Caesioperca rasor	Barber perch	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Canthigaster callisterna	Clown toby	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3	1	0	0	1	5	13
Carcharius taurus	Grey Nurse Shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Cheilodactylus fuscus	Red morwong	21	9	5	7	34	11	13	11	19	12	25	16	55	41	39	72	21	9	0	11	6	4	0	3	17	5	12	0	11	27	3	519
Cheilodactylus spectabilis	Banded morwong	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Cheilodactylus vestitus	Crested morwong	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chelmonops truncatus	Eastern talma	5	0	0	0	13	2	10	6	13	6	5	8	6	12	5	3	2	2	0	5	2	0	0	3	2	0	6	2	1	0	0	119
Chironemus marmoratus	Kelpfish	0	0	6	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	1	12	4	0	1	0	30
Chromis hypsilepis	One-spot puller	0	575	428	107	5	8	0	0	0	23	0	0	0	0	458	67	0	1	0	0	0	437	334	0	0	351	205	90	194	190	372	3845
Chromis nitida	Yellow-back puller	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chromis weberi	Weber's Chromis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Pagrus auratus	Snapper	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	1	20	1	0	1	0	0	0	0	0	0	0	1	0	9	0	37
Clupeoids unidentified	Herrings	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150
Cnidoglanis macrocephalus	Estuary catfish	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
Coris picta	Comb wrasse	0	0	1	0	1	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	1	0	0	0	2	0	0	0	1	0	13
Coris sandageri	King wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Crinodus lophodon	Rock cale	3	3	38	12	5	4	7	23	15	37	6	1	13	1	17	34	2	4	0	5	7	25	44	0	10	9	81	9	0	5	0	420
Dasyatis brevicaudata	Smooth stingray	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Dasyatis thetidis	Black stingray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Dicotylichthys punctulatus	Three-bar porcupinefish	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Dinolestes lewini	Long-fin pike	12	10	2	39	73	28	54	0	1	6	2	4	11	15	33	66	6	36	0	1	3	1	6	2	1	5	5	14	9	9	66	520
Diodon nicthemerus	Globe fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Ellerkeldia wilsoni	Spotty seaperch	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Enoplosus armatus	Old wife	4	7	6	2	3	1	61	43	47	15	6	6	65	15	41	18	59	31	3	28	145	8	6	51	16	6	4	60	20	6	20	803
Eubalichthys bucephalus	Black reef-leatherjacket	2	4	1	1	3	0	3	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	1	2	0	11	3	0	38
Eubalichthys mosaicus	Mosaic leatherjacket	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	6
Eupetrichthys angustipes	Snake-skin wrasse	0	0	1	8	5	19	2	0	3	0	0	0	2	1	10	14	10	2	2	2	0	0	0	4	0	0	1	0	0	5	0	91
Fistularia commersonii	Bluespotted Cornetfish	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4
Gerres subfasciatus	Common silver belly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Girella elevata	Rock blackfish	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	1	0	12
Girella tricuspidata	Luderick	0	5	0	0	0	0	0	0	0	0	0	0	0	0	66	22	0	128	0	1	0	2	6	0	0	0	0	0	0	0	0	230

Halichoeres margaritaceus	Pink-belly wrasse	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Halichoeres nebulosus	Clouded wrasse	0	0	0	0	3	4	2	0	0	0	0	0	0	0	28	20	1	0	0	0	0	0	0	0	0	0	0	1	0	4	0	63
Heterodontus portusjacksoni	Port Jackson shark	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	6
Hypoplectrodes annulatus	Black-banded seaperch	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	5
Hypoplectrodes maccullochi	Half-banded seaperch	9	9	37	39	13	29	11	17	14	1	4	8	1	3	12	9	3	1	1	1	0	8	7	2	4	40	4	11	28	52	35	413
Hypoplectrodes nigroruber	Banded seaperch	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	4
Hyporhamphus australis	Eastern garfish	0	200	0	0	0	0	0	0	0	45	0	50	201	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	100	626
Kyphosus sydneyanus	Silver drummer	0	0	1	0	0	0	0	0	1	0	0	0	0	0	9	0	0	1	0	0	0	1	0	0	0	2	3	1	0	4	0	23
Labroides dimidiatus	Cleaner wrasse	0	0	0	0	0	2	0	0	0	0	0	1	0	0	3	2	1	0	0	0	0	0	0	0	0	1	0	0	1	2	2	15
Leptojulis cyanopleura	Blue-spot wrasse	0	0	3	3	3	16	1	2	1	0	0	0	0	0	0	21	3	0	0	0	0	1	0	0	0	0	0	0	0	1	0	55
Lotella rhacina	Beardie	2	1	1	3	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	4	1	19
Macropharyngodon negrosensis	Yellow spotted wrasse	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	4
Mecaenichthys immaculatus	Immaculate damsel	1	1	0	3	6	4	6	12	8	0	0	8	9	3	0	1	9	11	0	1	0	0	0	0	1	0	0	0	5	3	0	92
Meuschenia flavolineata	Yellow-stripe leatherjacket	0	1	4	2	1	0	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	6	20	6	1	5	57
Meuschenia freycineti	Six-spine leatherjacket	0	3	0	0	2	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1	2	2	5	0	1	21
Meuschenia hippocrepis	Horseshoe leatherjacket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Meuschenia trachylepis	Yellow-finned leatherjacket	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	5	0	15
Meuschenia venusta	Stars and stripes leatherjacket	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4
Microcanthus strigatus	Stripey	2	10	6	16	0	1	0	1	2	0	0	2	0	0	10	0	0	0	2	0	0	0	0	0	0	1	31	0	5	8	4	101
Monodactylus argenteus	Silver batfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
Mugil cephalus	Sea mullet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	630	0	0	0	0	0	0	0	0	0	0	0	0	0	630
Nelusetta ayraudi	Chinaman leatherjacket	0	0	0	0	0	0	11	0	0	0	0	0	14	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	29
Nemadactylus douglasi	Blue morwong	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	1	0	0	0	0	0	1	2	0	11
Neoodax balteatus	Little rock whiting	0	0	0	0	3	0	0	2	0	0	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	11
Notolabrus gymnogenis	Crimson-banded wrasse	34	9	23	16	86	49	52	11	25	23	12	75	90	27	10	72	26	30	9	8	10	8	10	22	31	12	21	11	17	20	28	877
Octopus tetricus	Octopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Odax acroptilus	Rainbow cale	1	0	1	1	5	2	5	1	2	0	0	4	0	0	1	4	7	1	2	1	2	0	0	0	1	0	0	0	0	0	2	43
Odax cyanomelas	Herring cale	26	0	3	0	1	2	31	27	17	3	21	14	18	8	4	15	8	1	5	21	24	3	1	24	50	1	0	0	1	1	3	333
Ophthalmolepis lineolata	Maori wrasse	45	11	7	25	46	52	31	2	33	10	16	38	37	14	12	25	26	16	0	4	1	13	3	7	11	3	15	5	33	50	8	599
Optivus elongatus	Slender roughy	0	0	0	0	0	0	0	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Orectolobus maculatus	Spotted wobbegong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Orectolobus ornatus	Ornate wobbegong	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	6
Ostracion cubicus	Yellow Boxfish	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Paracaesio xanthura	Southern fusilier	0	0	0	0	3	1	0	0	0	0	0	7	0	0	0	1	6	0	0	0	0	0	0	0	0	0	1	0	0	0	4	23
Parapercis ramsayi	Spotted grubfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Paraplesiops bleekeri	Eastern blue devil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Parequula melbournensis	Silverbelly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Parma mccullochi	McCulloch's scalyfin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	23
Parma microlepis	White-ear	32	71	86	125	7	76	47	9	28	41	22	23	24	23	65	69	29	24	0	1	0	12	51	3	21	140	21	59	75	78	69	1331
Parma unifasciata	Girdled parma	0	2	22	0	0	1	2	0	0	0	0	0	3	9	1	1	0	0	0	0	0	5	5	0	0	2	68	70	0	0	0	191
Parupeneus signatus	Blackspot goatfish	76	0	2	0	101	91	8	4	15	3	11	56	28	52	29	63	42	154	0	8	0	0	0	37	20	2	1	0	2	4	15	824
Pempheris affinis	Black-tipped bullseye	20	5	0	2	43	133	3	17	92	0	5	143	31	31	2	35	78	4	0	13	0	1	5	2	0	0	0	0	23	49	100	837
Pempheris compressa	Small-scale bullseye	33	125	0	109	0	32	75	141	78	23	42	106	117	3	313	865	155	62	0	22	0	189	127	1	0	187	358	124	78	240	91	3696
Pempheris multiradiata	Common bullseye	10	0	0	5	7	53	3	10	24	0	10	2	108	7	1	5	105	15	0	3	0	0	0	1	0	0	0	0	45	77	243	734
Petroscirtes fallax	Yellow Sabretooth Blenny	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5
Phyllopteryx taeniolatus	Weedy seadragon	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pictilabrus laticlavius	Senator wrasse	6	0	4	2	34	21	36	12	15	3	5	4	20	8	1	21	9	3	17	12	4	0	1	6	4	1	6	0	1	0	8	264
Plagiotremus rhinorhynchos	Tube-worm blenny	0	4	0	0	0	0	1	0	0	0	0	40	0	0	1	0	0	0	0	0	0	1	0	0	0	1	2	0	0	1	0	51
Plagiotremus tapeinosoma	Hit and run blenny	2	1	0	0	3	7	0	6	1	0	0	1	2	1	8	3	1	3	0	0	0	0	0	0	2	1	0	0	2	1	1	46

Pomacentrus coelestis	Neon damsel	1	0	21	6	2	9	3	0	0	0	1	0	0	4	67	31	0	0	0	0	0	0	0	0	0	20	0	0	0	2	1	168
Prionurus microlepidotus	Sawtail surgeonfish	3	0	1	1	1	0	0	0	0	0	3	0	2	17	1	0	0	3	1	8	10	0	0	0	1	0	2	0	0	0	0	54
Pseudocaranx dentex	White Trevally	0	0	0	3	0	0	135	0	0	7	0	0	0	0	0	43	20	0	0	0	0	0	0	0	0	0	2	72	1	170	2	455
Pseudolabrus guntheri	Gunthers wrasse	9	0	0	0	0	1	0	0	1	0	0	0	1	2	1	4	4	6	0	0	1	2	0	0	0	0	1	0	1	0	2	36
Pseudolabrus luculentus	Luculentus wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3
Ptereleotris evides	Arrow goby	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	6
Ptereleotris microlepis	Pearly dart goby	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Ptereleotris monoptera	Lyre-tail Dart-Goby	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	88
Rhabdosargus sarba	Tarwhine	0	0	0	0	21	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Schuettea scalaripinnis	Eastern pomfret	168	0	0	0	0	0	28	39	0	60	238	30	180	445	755	102	15	10	30	30	4	0	100	0	28	525	0	0	0	0	1147	3934
Scobinichthys granulatus	Rough leatherjacket	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	4	0	0	0	0	0	2	12
Scomber australasicus	Slimy mackerel	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41
Scorpaena cardinalis	Red rock cod	1	4	1	0	1	0	0	2	2	0	1	0	0	0	0	1	0	0	0	2	0	1	0	0	0	2	1	1	4	8	0	32
Scorpis lineolata	Silver sweep	13	3	112	3	11	18	33	0	5	4	17	1	193	313	1	0	17	0	4	26	68	28	32	81	3	28	0	20	1	4	0	1039
Sepia apama	Giant cuttle	0	0	0	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	8
Sepioteuthis australis	Southern calamary	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Siphamia cephalotes	Little siphonfish	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	2	0	0	0	0	0	0	0	22
Stethojulis interrupta	Cut-ribbon wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	20
Stethojulis strigiventer	Three-ribbon Wrasse	0	0	0	1	4	2	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	14
Stethojulis trilineata	Blue-ribbon wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Stethojulius bandanensis	Red-spot wrasse	0	0	2	0	0	0	0	0	0	0	0	0	0	0	19	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
Suezichthys arquatus	Painted rainbow wrasse	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Suezichthys aylingi	Crimson cleaner fish	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Suezichthys devisi	Gracilis wrasse	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Thalassoma amblycephalum	Two-tone wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Thalassoma lunare	Moon wrasse	4	0	0	0	0	1	0	3	0	0	1	0	0	1	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	17
Torquigener pleurogramma	Banded toadfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Trachichthys australis	Roughy	1	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	10
Trachinops taeniatus	Eastern hulafish	47	7330	3325	2870	265	903	117	60	8	1150	20	476	669	525	2445	185	38	76	0	0	0	1968	1457	0	0	2738	2460	3089	3405	1855	1970	39451
Trachurus novaezelandiae	Yellow-tail scad	1691	244	0	72	0	266	1350	395	635	46	1	0	225	10	2340	10	250	0	55	10	10	0	0	40	1085	3	0	55	1	2	920	9716
Trygonoptera testacea	Common stingaree	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
Trygonorrhina fasciata	Fiddler ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Unidentified fish	Unidentified fish	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	3
Upeneichthys lineatus	Blue-lined goatfish	0	0	3	0	3	3	2	0	1	0	0	7	16	4	4	30	5	2	0	1	2	1	0	0	1	0	0	1	2	2	12	102
Urolophus kapalensis	Stingaree	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Valencienna strigata	Golden-head sleeper-goby	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Xyrichtys dea	Leaf wrasse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Zanclus cornutus	Moorish idol	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	5
Species Diversity		38	32	41	38	45	47	42	35	40	27	30	40	41	41	53	56	44	41	17	35	21	33	26	26	28	42	33	31	42	57	41	

Appendix 3. Large mobile invertebrate and cryptic fish abundance totals per site recorded during surveys at Jervis Bay in May 2006.

	Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**Total**
Species	**Common Name/Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**30**	**2**	**3**	**26**	
Cryptic Fish																																	
Acanthistius ocellatus	Eastern wirrah	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
Aploactisoma milesii	Velvetfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Apogon limenus	Sydney cardinalfish	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Asymbolis analis	Spotted Catshark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Clinid spp.	Weedfish	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Cnidoglanis macrocephalus	Estuary catfish	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
Diodon nicthemerus	Globe fish	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Goby spp	Goby	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	5
Gymnothorax prasinus	Green moray	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	3	2	0	0	0	4	13
Heterodontus portusjacksoni	Port Jackson shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Hypoplectrodes annulatus	Black-banded seaperch	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hypoplectrodes maccullochi	Half-banded seaperch	2	7	0	12	6	3	0	1	4	0	7	1	1	0	0	6	1	3	0	0	0	4	18	0	0	29	3	0	12	0	27	147
Hypoplectrodes nigroruber	Banded seaperch	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lotella rhacina	Beardie	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	5
Optivus elongatus	Slender roughy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Paraplesiops bleekeri	Eastern blue devil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Phyllopteryx taeniolatus	Weedy seadragon	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scorpaena cardinalis	Red rock cod	0	0	0	0	0	0	1	0	1	0	1	1	2	0	0	0	0	0	2	0	0	0	0	1	0	0	1	0	0	0	0	10
Scorpaena papillosa	Southern rockcod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Thysanophrys cirronasus	Rock flathead	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ascidian																																	
Herdmania grandis	red-throat ascidian	146	1	46	6	32	15	97	396	98	1	152	32	117	127	9	9	12	61	120	361	600	3	9	286	170	14	27	0	58	28	154	3187
Echinoderm																																	
Amblypneustes ovum	Short-spine urchin	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	4	0	0	1	0	0	0	0	0	0	0	8
Cenolia trichoptera	Featherstar	0	0	0	0	0	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	23	31
Centrostephanus rodgersii	Long-spine urchin	139	619	502	434	42	216	83	35	135	274	157	5	201	208	451	748	383	285	1	3	2	1762	589	13	142	418	608	0	67	325	74	8921
Fromia polypora	Seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Goniocidaris tubaria	Pencil urchin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Heliocidaris erythrogramma	Common urchin	1	0	0	0	1	0	0	0	0	8	0	0	38	0	0	0	0	0	115	45	582	3	0	84	6	0	1	0	0	0	0	884
Heliocidaris tuberculata	Urchin	0	0	0	1	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	25
Pentagonaster dubeni	Fire-brick star	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	0	0	7	0	6	18
Petricia vernicina	Velvet star	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Phyllacanthus parvispinus	Eastern slate-pencil urchin	5	0	2	0	1	0	0	6	18	0	2	1	0	24	0	1	0	0	2	6	1	0	0	0	7	3	0	0	26	3	19	127
Plectaster decanus	seastar	0	0	2	1	0	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	5	3	18
Uniophora granifera	Seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Mollusc																																	
Aplysia spp.	Sea hare	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Astralium squamiferum	Turban shell	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	11
Astralium tentoriformis	Turban shell	22	158	191	223	24	76	53	77	17	6	76	30	96	157	234	44	11	22	33	56	45	145	199	66	47	576	97	0	63	93	140	3077

Cabestana spengleri	Triton shell	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	3	0	1	0	0	10
Cabestana tabulata	Trumpet shell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Charonia lampas rubicunda	Triton shell	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	3	11
Conus anemone	Cone Shell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cymatium parthenopeum	Trumpet shell	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	4
Dicathais orbita	Dog whelk	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	10	0	0	3	5	0	0	0	0	22
Haliotis rubra	Blacklip abalone	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	13
Octopus tetricus	Octopus	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5
Phasianella australis	Pheasant shell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Sepia apama	Giant cuttle	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
Sepia plangon	Mourning cuttle	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Turbo torquatus	Periwinkle	1	0	0	0	0	1	0	0	1	10	6	8	4	1	1	64	2	0	2	2	2	0	0	4	5	0	1	0	0	0	0	115
Turbo undulatus	Periwinkle	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Crustacean																																	
Hermit crab unidentified	Hermit crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
Jasus verreauxi	Eastern rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
Nectocarcinus tuberculatus	Velvet crab	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pagurid spp.	Hermit crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Plagusia chabrus	Red bait crab	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	5
Species diversity		**12**	**6**	**6**	**10**	**10**	**11**	**7**	**8**	**16**	**10**	**11**	**13**	**10**	**10**	**8**	**7**	**9**	**6**	**12**	**8**	**11**	**7**	**8**	**14**	**12**	**9**	**13**	**0**	**14**	**5**	**18**	

Appendix 4. cont. Large mobile invertebrate and cryptic fish abundance totals per site recorded during surveys at Jervis Bay in May 2007.

	Depth	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10	10	10	Total
Species	**Common Name/Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**30**	**2**	**3**	**26**	
Cryptic Fish																																	
Cnidoglanis macrocephalus	Estuary catfish	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Gymnothorax prasinus	Green moray	0	0	0	0	0	0	0	0	1	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	7
Heterodontus portusjacksoni	Port Jackson shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Hypoplectrodes maccullochi	Half-banded seaperch	0	5	22	6	4	0	0	0	0	3	0	6	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	19	67
Scorpaena cardinalis	Red rock cod	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Scorpaena papillosa	Southern rockcod	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4
Ascidian																																	
Herdmania grandis	red-throat ascidian	51	8	1	9	25	29	116	133	67	3	85	28	42	28	9	22	21	39	314	214	526	26	26	255	109	24	8	0	59	46	49	2372
Echinoderm																																	
Amblypneustes ovum	Short-spine urchin	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	4
Cenolia trichoptera	Featherstar	0	0	0	0	1	1	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	4	0	8	2	11	31
Centrostephanus rodgersii	Long-spine urchin	86	455	632	272	32	138	48	46	77	312	78	80	92	95	331	460	307	121	0	2	7	847	359	15	131	201	454	596	94	222	64	6654
Echinaster arcystatus	Seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Fromia polypora	Seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
Heliocidaris erythrogramma	Common urchin	0	0	0	0	0	0	0	0	0	26	0	0	0	2	0	0	0	0	37	26	71	0	0	3	16	0	4	0	0	0	0	185
Heliocidaris tuberculata	Urchin	0	0	4	0	0	0	0	0	0	16	0	0	18	0	0	1	0	0	0	0	0	7	6	0	0	0	1	2	0	0	0	55
Nectria ocellata	Ocellate seastar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
Pentagonaster dubeni	Fire-brick star	0	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	15
Petricia vernicina	Velvet star	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Phyllacanthus parvispinus	Eastern slate-pencil urchin	1	1	0	0	5	0	1	2	3	0	0	0	1	0	0	0	1	2	1	0	2	0	1	3	3	1	0	1	11	6	13	59
Plectaster decanus	seastar	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2	2	0	2	10
Tripneustes gratilla	Urchin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Mollusc																																	
Astralium tentoriformis	Turban shell	20	70	129	86	22	65	41	38	18	4	29	18	38	67	168	45	11	24	35	18	33	114	70	17	37	345	31	89	107	156	163	2108
Cabestana spengleri	Triton shell	0	2	1	0	0	0	0	0	0	15	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	0	5	35
Cymatium parthenopeum	Trumpet shell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
Dicathais orbita	Dog whelk	0	2	0	0	0	0	0	0	0	1	0	0	1	0	1	2	1	1	2	0	0	0	0	0	4	0	11	0	8	2	0	36
Haliotis rubra	Blacklip abalone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	1	0	0	0	0	4	0	0	0	0	0	1	0	0	61
Octopus tetricus	Octopus	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	7
Ranella australasia	Australian rock whelk	0	4	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	12
Sassia parkinsonia	Trumpet shell	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sepia apama	Giant cuttle	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	4
Turbo torquatus	Periwinkle	2	0	0	0	0	1	3	0	0	3	1	5	1	0	0	9	0	1	0	1	3	0	0	0	2	0	0	0	0	0	1	33

Crustacean																																	
Jasus verreauxi	Eastern rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Plagusia chabrus	Red bait crab	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	2	0	0	4	0	0	0	0	1	0	1	12
Thenus orientalis	Moreton Bay Bug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
Species diversity		**6**	**10**	**9**	**7**	**8**	**5**	**6**	**5**	**6**	**12**	**4**	**10**	**8**	**4**	**7**	**10**	**5**	**11**	**7**	**6**	**9**	**4**	**7**	**6**	**8**	**6**	**9**	**11**	**12**	**8**	**13**	

Appendix 9. Algal and encrusting/sessile invertebrate percentage cover per site recorded during surveys at Jervis Bay in May 2006.

Depth Species/Site	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9	5 10	5 11	5 12	5 13	5 14	5 15	5 16	5 17	5 18	5 19	5 20	5 21	5 22	5 23	5 24	5 25	5 26	5 27	5 30	10 2	10 3	10 26
Green Algae																															
Caulerpa cactoides	0	0	0	0	1.7	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulerpa flexilis	0	0	0	0	18.2	0.8	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
Codium fragile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0
Codium lucasi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0	0	0
Green turf	0	0	0	0	0	0	0	0	0	1.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0
Brown Algae																															
Brown turf	0	1.8	0	0	0	0	0	0	0	13.3	0.5	0	0	0	0	1.2	0	0	2	0	0	0	0	0	0	0.4	10.3	0	4.5	0	17.5
Cystophora monilifera	0	0	0	0	8.5	5.7	2.3	0	0	0	0	0	4.1	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Cystophora moniliformis	0	0	0	0	6.1	3.5	1.1	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyopteris muelleri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	1.3	0.4	0	0	0	0	0	0	0	0	0	0	0
Dictyota spp.	1.6	0	0	0	2	0	7.4	0	0.4	0	0	0.5	0	0	0	0	0.9	0	0	2.2	1.7	0	0	0	0	0	0	0	0	0	0
Dictyota spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0
Dilophus marginatus	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distromium flabellatum	0	0	0	0	0	0	0.6	0	0.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Ecklonia radiata	45.9	0	6	0	2.9	1	41.3	59.1	54	4.1	47	41.3	34.1	6.5	8.5	14.7	23.3	20.7	55.9	67.1	40.1	9	6.8	82	54.5	0	3	0	14.1	0	41.5
Encrusting brown algae	0.5	0	0	0	2	0	1.5	2.3	0	0	3.9	2.4	1.1	2.7	0	0.4	0.7	0	0	2.3	0.2	0	0	0.6	1.4	0	0	0	0	0	1.2
Halopteris spp.	1.6	0	0	0	0	0	0	0	0	0.5	0.2	0	0	0	0	0	0	0	0.5	0	0	0	0	0	3	0	0	0	0	0	0
Homoeostrichus olsenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0
Jervis Bay Sargassum A	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jervis Bay Sargassum B	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Lobophora variegata	7.3	0	0	0	28.8	5.4	9.1	9	6.9	5.9	3	6.3	12.7	4.2	0	0	4	0	2.5	3.5	6.6	0	0.2	3.2	6.4	0	0	0	4.1	0	8.1
Sargassum lacerifolium	0	0	0	0	8.2	2.9	9.6	0.8	4.4	0	3.3	8.2	0.4	1	0	0	2.9	0	0.6	1.6	0.6	0	0	0	1.8	0	0	0	0	0	0
Sargassum linearifolium	0	0	0	0	0	0.9	0	0	3.2	0	0	0.8	0	0	0	0	0	1.6	0	0	0.4	0	0	0	0	0	0	0	0	0	0
Sargassum spinuligerum	0	0	0	0	8	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum spp.	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0.2	0	0	0	0	0	1.4	0.8	0	0	0	0	0	0	0
Red Algae																															
Amphiroa anceps	2.3	0	8.8	0	0	0	0	0.1	0.9	13	1.1	0	0	0	2.1	0	0	0	0	0	3.3	0	2.3	0	5.4	0	4.5	0	4.1	0.5	0.5
Corallina officinalis	0.9	0	0	0	0	0	0	0	0.1	4.1	0.4	0.3	0	0	0	0	0	0	0	0	0	0	0.6	0	0.8	0	9	0	1.3	0	0
Crustose coralline algae	54	79	3	59.2	7.5	15.1	40	57	28	43.4	40.1	52.1	18.2	19.5	0	77.6	6.9	5.4	32.9	44.5	34.9	86.6	83	47.3	41.5	84.4	51.5	0	47.8	8.3	60.8
Filamentous red algae	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foliose reds	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geniculate coralline turf	1.6	0	0	0	1	2.2	0.2	0	1.8	2.4	2.9	1.8	1.3	0	0	0.8	3	0.6	0	0	0	0	0	0	0.3	0	0	0	0	0	0
Haliptilon roseum	0	0	0	0	0	0	0	0	0	1.5	0.6	0	2.1	0	0	0	0	0	0	0	0	0	1.5	0	0.2	0	0	0	0	0	0
Laurencia botryoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0
Laurencia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0.2	2.1	0	0	0.1	0	0	0	0	0	0	0
Other turf	19.5	10.2	0	25.5	6.8	48.3	0	14.6	20.3	7.5	30	15.6	29.6	30.6	3	10	49.9	69.3	2	1.4	6.6	0	1.6	10.6	18.8	5	10.1	0	13.6	0	0
Peyssonnelia flat	1.9	0	0	0	2.8	0	3.4	3.2	1.1	0.2	1.8	7.6	3.6	0	83.5	0.6	0	0.7	10.7	4.8	0.4	0.2	0.3	4.2	0	1.3	0	0	2	0	0.3
Peyssonnelia novaehollandiae	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plocamium cartilagineum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0

Plocamium leptophyllum	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Turf	1.5	0.1	0	0	0	0	0	0	6.7	0	2	0.9	0	0	0	5.7	8	1	11.8	0	0.9	0	7.4	1.6	0	0	2.2	0	0	0	0
Sporolithon durum	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Seagrass																															
Halophila ovata	0	0	0	0	7	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other																															
Anemones	0	0	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	1.2	0	0.5	0	0
Ascidians	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barnacles	5	0	0.2	11.8	0	0	0.8	0	0	0	0	0	0	0.5	7.4	0	0	0	0	0	0	1.1	0	0	0	3.5	11.7	0	0.7	0	0
Bryozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2
Centrostephanus rodgersii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
Cleithro sp.	0	14.1	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0
Corynactis australis	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0
Culicia spp.	0	2.6	0	1.4	0	0	0	0	0	0	0	0	0	0.2	1.8	0	0	0	0	0	0	0.2	0	0	0	6	1.5	0	1	0	7.2
Encrusting bryozoans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encrusting invertebrates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0
Erythropodium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	13.4	0	2.1
Hard bryozoans	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Herdmania grandis	2.6	0	0	0	0.4	0.2	1.5	7.3	1.2	0	1.8	0.4	1.3	1.6	0.5	0.6	0.4	0.5	2.7	4.7	5.4	0.6	0.6	3	3.2	0.4	0.8	0	1.6	1.3	1.4
Hydroids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mussel spp.	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.6	0	0	0	0	0	0	0	0	0	0
Plesiastrea versipora	0	0	0	0	0	1.8	0	0	0	0	0	0	0	8.3	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4
Screw ascidians?	3	0	0	0	0	0	2.5	1.2	3.8	0	1.2	1	0.2	0	0	0	2.6	1.3	1.2	4.9	3	0	0	2.9	0.9	0	0	0	0	0	0
Sponge (encrusting)	2	0.2	0	0	0.8	0	4.7	1	4.8	0	0	1.7	4.2	0.9	2.5	0	0	0	13.2	19.1	6.9	3	1.4	8	1.6	0	3.6	0	2.2	0	0
Sponges	0.3	0.4	0	0	0.2	0	0.4	1.3	0.2	0	4.55	0.2	1.7	0.7	0	0	0	0	7.1	5.9	0.3	0	0	8.5	0	1.8	0	0	2.3	0	0
Trichomya hirsuta	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Substrate																															
Bare rock (barrens)	40	100	67.3	100	10	75	15	0	10	50	29.8	15	25	80	85	85	55	60	0	0	5	90	85	5	5	100	85	0	0	74.6	15
Bare rock (non - barrens)	0	0	0	0.5	4.8	15	8	2	0	0	0	0.6	9.3	17.6	0	0	13.9	0	8.4	0	3.2	8.6	0	1.3	8.1	0	0	0	0	0	0.8
drift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0	0	0
Gravel	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	1	0	0
Sand	6.6	0	0	2.5	37.4	15.3	23.4	5.1	33	2.6	0	0.4	16.7	9	5	0	10.2	21.2	4.6	11	23.1	0	0.5	7	4.5	0	0	0	2.5	0	0.6
Silt on reef	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algal Diversity	**12**	**4**	**5**	**2**	**15**	**10**	**12**	**10**	**15**	**13**	**15**	**13**	**13**	**9**	**4**	**8**	**11**	**7**	**12**	**13**	**13**	**3**	**10**	**9**	**13**	**4**	**8**	**0**	**8**	**5**	**7**

Appendix Algal and encrusting/sessile invertebrate percentage cover per site recorded during surveys at Jervis Bay in May 2007.

Depth	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**
Species/Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**30**	**2**	**3**	**26**
Green Algae																															
Caulerpa cactoides	0	0	0	0	6.4	0	0	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulerpa flexilis	0	0	0	0	30.7	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha spp.	0	0	0	0	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Codium galeatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
Codium lucasi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Ulva spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown Algae																															
Acrocarpia paniculata	0						3.4																								
Brown turf	0	0	0	9.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cutleria multifida	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cystophora monilifera	0	0	0	0	3.6	5.1	0	0	0	0	0	0	2.7	0.3	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Cystophora moniliformis	0	0	0	0	0.4	0.6	1.5	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyopteris muelleri	0	0	0	0	0	0	0	0	0.3	0	0.2	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota dichotoma	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0.6	0	1.1	0	0	0	0	0	0	0	0	0	0	0
Dictyota spp.	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dilophus marginatus	0	0	0	0	0	0	0	0	0.4	0.1	0	0	0	0	0	0.2	0	0.4	0	0.1	0	0	0	0	0	0	1.4	0	0	0	0
Dilophus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.55	0.1	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
Distromium flabellatum	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0.6	1.9
Ecklonia radiata	42.8	0.5	0.8	0	2.6	4.1	43.7	65.6	47.8	6.5	75	32.9	36.6	23.5	2.5	14.7	8.6	24.6	85.5	80.6	95.7	31.4	7	81.6	91	0.4	5.2	0	8.7	0	16.8
Encrusting brown algae	0	0	0	0	0	0	0	1.6	0	0	0.3	0	0	0	0	0.7	0	12.8	0	0.6	0.9	0	0	0	1.7	0	0	0	0	1	4.5
Foliose browns	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halopteris spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0
Homoeostrichus olsenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0.4	0	0	0	0	0	0	0
Homoeostrichus sinclairii	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobophora variegata	11	0	0	0.4	23	4.1	16.8	5.9	8.2	0.1	1.1	8.6	4.2	6.1	0	0.4	3.5	10.2	0.5	6.8	0.3	0	0	6.3	7.4	0	0.5	0	1	0.9	9.1
Pachydictyon paniculatum	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Padina spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.1	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllospora comosa	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum fallax	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum lacerifolium	0.4	0	0	0	15.2	0.9	20.2	3.2	5.2	0	4	21.6	7.4	3.8	0	0	3	3.2	0.6	0.2	0	0	0	1.2	0.8	0	0	0	0	0	0
Sargassum spinuligerum	0	0	0	0	19.5	0.6	0	0	1.5	0	0	0	0	0	0	0	0	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum spp.	0.7	0	0	9.6	5	2.1	0	0.4	0.4	1.8	0.4	0.4	3.6	0.3	0.4	8.1	0.7	0	0.4	0.8	0.2	0	0	0.7	0	0	2.3	0	0.1	1.4	2.3
Zonaria spp.	0	0	0	0	0	0	0	0	0	12.1	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Algae																															
Amphiroa anceps	5.2	0	0	0	0	0	0	0.3	0.1	7.9	0.4	0.5	0	0.1	1.5	0	0	0.6	0	0	1.4	3.8	1.8	0	5.3	0	5.4	0.93	3	6.7	1.8
Corallina officinalis	0.9	0	1.6	0	0	0	0	0	0	2.2	0.2	0	0	0	0	0	0	2.8	0	0	0.2	0	0	0	0.2	0	0	0	0.1	0	0
Crustose coralline algae	35.6	81.6	72.1	57.4	15.8	16.2	47.5	54.9	25.5	50.1	45.9	20.6	14	14.5	52.7	43.8	6.7	18.6	31.6	50.5	50.2	64.1	90	36.2	55.4	87.9	44.2	58.7	67.6	57.4	58.7
Erythroclonium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	5.2	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	3.2	0	5.3
Filamentous red algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Foliose reds	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliptilon roseum	0	0	5	0	0	0	0	0	0	10.7	0	0.3	1.9	0.5	2.1	0.6	0.1	0	0	0	0	0.4	2.4	0	0	0	3.3	1.6	0	0	0.4
Hildenbrandia spp.	0	0	3.6	1.2	0	0	0	0	0	6.2	0	0	0	0	0.7	2.2	0	0	0	0	0	33.2	15.4	0	0	3.8	0	0	0	0	0
Laurencia filiformis	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.5	0	0	0	0	0	0	0
Laurencia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other turf	0	6.1	14.2	16.6	6.1	0	0.8	0	35.1	0	7.5	0	0	0	0	0	0	23.15	5.6	2.5	0	0	0	4.9	6.6	0	0	3.2	0	18.6	0
Peyssonnelia flat	2.2	0	0	2.2	0.2	1.6	1.9	0.7	0.2	0	1.8	1.2	2.4	1.1	0	0.6	0	0.3	15.3	2.9	0.5	0	0	2.7	0.7	0	0.7	0.4	1.4	0	0.1
Peyssonnelia novaehollandiae	0	0	0	0	0	0	0	2.5	0	0	0	0.3	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0
Plocamium cartilagineum	0	0	0	0	0	0	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0
Red Turf	0	0	10.8	9.3	0	0	0	0.8	0	16	1.4	0	8.9	3.5	2.5	20.2	15.3	0	0	0.9	0	0	0	0	0	0	31.4	4.6	2.5	0	0
Rhodymenia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Seagrass																															
Halophila australis	0	0	0	0	0	0	2.1	0	0	0	0	0	0	0	0	0	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterozostera tasmanica	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other																															
Anemones	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	4.8	0	0	0
Anthothoe albocincta	0	0	0.8	0	0	0	0	0	0	0.6	0	0	0	0	0.3	0.7	0	0	0	0	0	0	0	0	0	0	1.7	2.67	0.2	0	0
Ascidians	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0	0	0	0.1	0	0.1	0.3	0	3.4	1.2	0	0.4	0	1.7	4.13	0	0	1.8
Barnacles	10.8	8.2	7.33	6.3	0	9.9	0	0	2.6	2.3	1.5	2.7	1	0.9	2.9	0.2	6.1	4	0	0	0	24.6	5	0	0	13.3	5.2	5.29	1.5	14.9	0.85
Bivalves	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachiopods	0.6	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellana tramoserica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0
Cleidothaerus albidus	0	0	0	0	0	0	0	0	0	0	0	0.1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cnemidocarpa pedata	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corynactis australis	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corynactis spp.	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0.5	1.87	2.1	0	0.8
Culicia spp.	0	3.7	0	0	0	0.2	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	9.8	7	0	0	3	0.2	24.4	0	2.5	3.1
Culicia tenella	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.7	0	0	0
Diopatra tubes	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drift	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.6	0	0	0	0	0	0	0
Encrusting bryozoans	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1.87	0	0	0
Hard bryozoans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0.1	0	0	0	0	0	0	0.13	0	0	0.2
Herdmania grandis	2.5	0	0	0	0	0.8	1.4	3.6	0.9	0	1.2	0	2.3	1	0	0	0	0.3	3.7	6.8	5	1	0	4	3.1	0.8	1.3	0	0	0	0
Hydroids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0
Mopsella spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Mussel spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	1.3	0	0	0	0	0	0
Plesiastrea versipora	0	0	0	0	0	2.6	0	0	0.2	0	0	0	0	5.6	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.4	0
Pyura spinifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0.6	0	0
Salmacina spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.13	0	0	0
Screw ascidians?	4.4	0	0	1.2	0.8	2.7	2	7.3	6.9	0	0.4	0	0	0	0	0	0	0.2	2.5	1.4	7.1	0	0	2.6	4	0	0	0	0	0	0
Serpulorbis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Sponge (encrusting)	3	2.6	1.8	0	2.1	0.2	5.8	3	8.1	1.5	24.3	0.6	11.6	0	0	1.3	0.6	1.1	26.3	11.8	33.7	0.8	3.6	18.6	10.9	2.2	2.4	9.2	1.5	0.3	1.5
Sponges	0.5	0.4	0	0.6	0	0	3	1.4		0	1.9	0	0.3	4.7	0.3	0	0	0	8.8	9.3	1.9	0	1	3.8	0.5	0	0	0.8	0.7	0	0
Triphyllozoon spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0

Zoanthus sp. (Jervis Bay)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
Substrate																															
Bare rock (barrens)	40	99	92	80	0	70	10	10	20	60.7	20	26.5	29	57.5	81.6	51.2	6.3	49	0	0	0	71.5	89.5	0	0	99.8	55.9	85.7	23.5	95	12
Bare rock (non - barrens)	1.5	0	3	0	4.5	31.4	9.4	13	10.1	0	6.4	0	0	0	0	0	0	6.5	0.7	0	0	37.4	1.2	0	0	3.6	0	0	0	0	0
Gravel	0	0.5	0	1	5	5	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	4.4	0	0	0	0.8	0
Sand	9.5	0	3.6	9.33	31.1	6.2	12.3	14.1	2	0	1.2	0.8	13.8	7.6	14.2	2.6	22.9	0.1	5.9	7.8	13	0	0	18.1	8.8	0	0.5	0	7.5	5.5	3.7
Turf/sand/sediment matrix	28.9	0	0	0	0	24.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Algal Diversity	**10**	**4**	**7**	**9**	**14**	**10**	**10**	**13**	**13**	**13**	**12**	**10**	**12**	**13**	**7**	**12**	**13**	**14**	**10**	**15**	**8**	**5**	**5**	**11**	**10**	**3**	**11**	**6**	**10**	**7**	**10**